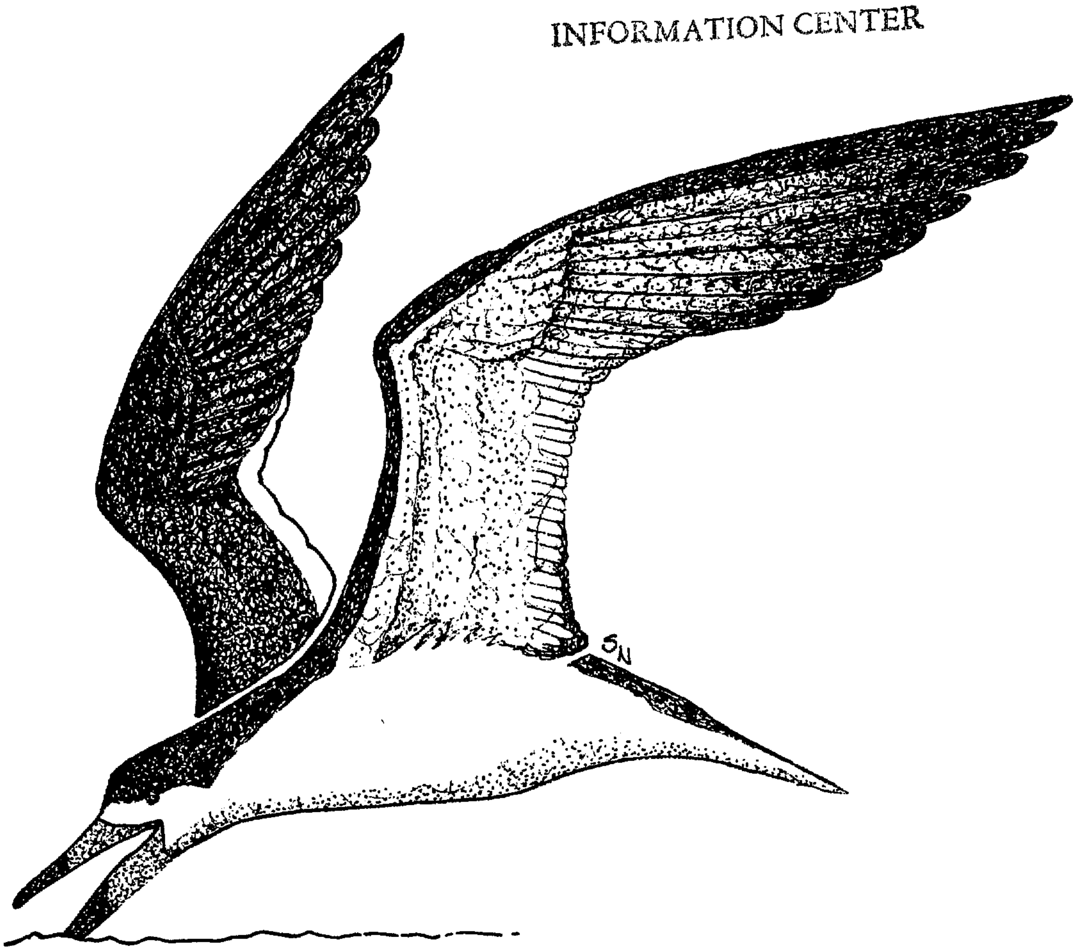
Florida Game and Fresh Water Fish Commission
Nongame Wildlife Program

Technical Report No. 1

Human and Natural Causes of Marine Turtle Nest and Hatchling Mortality and Their Relationship to Hatchling Production on an Important Florida Nesting Beach



Game & Fresh Water Fish Commission

April 1987

Human and Natural Causes of Marine Turtle Nest and Hatchling Mortality and Their Relationship to Hatchling Production on an Important Florida Nesting Beach

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ABSTRACT

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Populations of Western Atlantic loggerheads (*Caretta caretta*) and Florida Green turtles (*Chelonia mydas*) have been in historical decline. The identification and protection of beaches that are major producers of loggerhead and green turtle hatchlings are vital to the preservation of these species.

A study assessing loggerhead and green turtle hatchling production was initiated at a 21 km stretch of beach in south Brevard County, Florida (Melbourne Beach) during the 1985 nesting season. Nesting densities were assessed from a season-long (10 May - 12 September) census, in which every nest was counted and identified to species. An analysis of average reproduction success was made from 100 loggerhead and 27 green turtle sample nests. Daily tallies of specific disturbances to nests aided in formulating dimensional descriptions of factors which caused clutch and hatchling mortality.

An unprecedented 10,240 loggerhead and 281 green turtle nests were counted within the Melbourne Beach study area in 1985. Approximately 48 and 51 percent of the constituent eggs of loggerhead and green turtle nests resulted in hatchlings that successfully entered the surf. These values are very high compared to data from other nesting beaches.

A severe September northeaster storm was the major cause of mortality for clutches of both species. Raccoon predation and the disorientation of hatchlings by beachfront lighting were also significant in limiting reproductive success. Beachfront lighting was also found to significantly deter green turtles from nesting. Predation of nests by raccoons was limited to a small portion of the study area. The rate of hatchling disorientation was found to decrease following the enforcement of a regional ordinance restricting beachfront lights.

Management recommendations include: bestowing a special protective status for the Melbourne Beach area; providing efforts to monitor and regulate beach and nearshore activities; initiating specific management practices to mitigate mortality; and enhancing research and public education efforts regarding Melbourne Beach's marine turtles.

ACKNOWLEDGEMENTS

The financial support for this research was provided by a contract with the Nongame Wildlife Program of the Florida Game & Fresh Water Fish Commission. We acknowledge that support with sincere thanks and also thank the staff members of the program with whom we worked: Jim Cox, Brad Gruver and David Cook. They maintained a cooperative, business-like relationship throughout the course of the contract. We work continuously with the professional cooperation of Major Robert Patterson and his staff at the Titusville headquarters of the Florida Marine Patrol. Also, the dispatchers and south Brevard deputies of the Brevard County Sheriff's Department are always courteous and helpful. We thank both law enforcement agencies.

Once again this year the Board of County Commissioners of Brevard County generously provided a special permit for use of three-wheel motorcycles on the beach. We thank them for the privilege.

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We thank the Indian River Audubon Society for its continuous support of our work in south Brevard County. Also we are grateful to Capt. Perry Smith and his staff at Sebastian Inlet State Recreation Area and the management of Holiday Haven Mobile Home Park, who tolerate our seemingly bizarre activities. Stewart Marcus, of Hobe Sound National Wildlife Refuge, provided useful, but otherwise unavailable, comparative data and Dr. Haven C. Sweet, of UCF, provided hardware, software and sound advice for the computer analysis. We thank them all.

A special note of thanks goes to Paul W. Raymond of the National Marine Fisheries Services (NOAA) in St. Petersburg. He helped in the field when he could and was instrumental in the creation of our computer graphics. More importantly, however, as the one who single-handedly began the work at Melbourne Beach four years ago, he continues to be the philosophical and practical conscience for the continuing work on that beach.

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INTRODUCTION

Florida's beaches serve as regular nesting locations for three species of marine turtles. Of these three, the Atlantic loggerhead (Caretta caretta caretta) is the most abundant. Though rare by comparison, a significant number of animals from the remnant population of Florida green turtles (Chelonia mydas mydas) also nest in Florida. Atlantic leatherbacks (Dermochelys coriacea coriacea) nest sparsely in Florida, which constitutes the northern extent of their nesting range (Pritchard, 1979).

All these marine turtles are believed to be in serious worldwide decline (Ross, 1982; King 1982). The loggerhead (threatened), the green turtle (endangered) and the leatherback (endangered) are all protected under the terms of the Endangered Species Act of 1973. In Florida, historical glimpses of nesting marine turtle abundance exist only as anecdotes (Audubon, 1926). These accounts frequently lack assured species identifications and make the past relative abundances of species rather enigmatic. There is, however, nothing in the literature that contradicts the belief that past population densities were much higher than present ones.

Historically, the principal cause of the decline of marine turtle populations has been unregulated harvest at all life history stages, egg to adult. Though protected from exploitation in the U.S., these animals face other direct threats. The explosive proliferation of human development along Florida's coast may be the most severe of these. The presence of beach degrading structures constricts present nesting areas and is likely to severely limit the number of beaches suitable for nesting in the future (Coston-Celments and Hoss, 1983).

Beaches where significant numbers of marine turtles still nest are vital sources of recruitment for these waning populations. To identify major areas of marine turtle nesting in the U.S., Hopkins and Richardson (1984) reviewed aerial and ground reconnaissance data from several sources. The resulting compendium suggested that a stretch of beach from Melbourne Beach to Sebastian Inlet in South Brevard County, Florida, supported the largest aggregation of nesting loggerheads in the U.S. Separate aerial surveys of Florida (the most densely nested state by far) reinforce these findings (Carr and Carr, 1977; Murphy and Hopkins, 1984).

In 1981, Ehrhart and Raymond (1983) initiated a systematic, season-long survey of nesting activity on a stretch of beach at Indialantic and Melbourne Beach, Florida. High loggerhead nesting densities were found, with a disproportionate increase in nesting densities in the southern sections of the study area (near Melbourne Beach). The study area was extended southward in 1982 to include the area from Melbourne Beach to Sebastian Inlet. Estimates of loggerhead nesting at this 21 km beach were calculated to be 9,432 and 7,753 clutches in 1983 and 1984 (Ehrhart and Raymond, ms.). These estimates correspond to an unprecedented 450 and 370 nests per kilometer. Information on loggerheads nesting elsewhere in the Western Atlantic suggests that the density of females that nest on this South Brevard beach is unsurpassed in this hemisphere (Ross, 1982). Ross recognized that the population that nests in the

Southeastern U.S. is second in size only to that which breeds at Masirah, an island off the Oman coast in the Indian Ocean. This Indian Ocean population may or may not have a different subspecific identity (Caretta caretta gigas; Pritchard, 1979).

The term "Florida green turtle" is not a taxonomic distinction but will be used henceforth to identify those turtles which nest almost exclusively in Florida. These animals may be remnants of a larger population whose nesting grounds were disjunct from other Atlantic populations. The only significant nesting of Florida green turtles occurs on the central-southeast coast of Florida (Dodd, 1981). Even within this restricted area, very few stretches of beach are reported to host an excess of one nest per kilometer (Hopkins and Richardson, 1984). Florida green turtle nesting densities on the South Brevard beach (21km) were found to average approximately 2.2 and 1.6 nests per kilometer in 1983 and 1984 (Ehrhart and Raymond, ms.).

Marine turtles are recognized nonconformers to the prescribed r-K selection continuum (Ehrhart, 1982). While adults display a relatively horizontal survivorship curve, eggs and hatchlings suffer tremendous losses during these short life history stages. The reproductive strategy of marine turtles is to anticipate these huge losses with a profusion of eggs and resultant hatchlings. This strategy dictates laying large clutches of eggs multiple times over several nesting seasons. It is currently uncertain what losses eggs/hatchlings can incur and still provide stasis-maintaining recruitment (Richardson, 1982).

Very few accurate assessments of natural hatchling recruitment from marine turtle nesting beaches exist in the literature. Most accounts of "hatchling production" or "hatch rates" refer to artificial hatchery operations (Richardson, 1978; Andre and West, 1981; Bustard, 1972) or experimentally manipulated clutches of eggs (Bustard, 1971; McGehee, 1979; Ackerman, 1980). Other studies involve naturally deposited nests in situ, though concentrate primarily on elucidating rates of major predation (Gallagher, 1972; Davis and Whiting, 1977; Anderson, 1981; Hill and Green, 1971) and seldom quantify mortality beyond major disturbances to nests. Some studies exist that identify both conspicuous and subtle mortality factors (Mortimer, 1981; Schulz, 1975; Carr and Hirth, 1962; Ragotzkie, 1959; Balazs, 1980; Bjorndal et al., 1985), but concentrate primarily on comparisons of reproductive success between similarly sampled nests on the same beach or the establishment of baseline reproductive success for undisturbed nests. Such studies typically sample only from nests exhibiting hatchling emergences, nests from limited areas or limited numbers of nests, rendering the extrapolation of nest reproductive success to beach productivity refutable. Studies that present relatively unbiased assessments of marine turtle reproductive success applicable to nesting beach hatchling production exist only for South Carolina loggerhead nesting beaches (Hopkins et al., 1978; Caldwell, 1959a) and the Tortuguero, Costa Rica green turtle nesting colony (Fowler, 1979).

Although estimates of nesting beach productivity are rare, approximations of maximum productivity may be made using frequently reported rates of nest predation, assuming that nests not depredated display predictable success. By far, the most significant predator of marine turtle nests in the U.S. is the raccoon (Procyon lotor). Estimates of damage caused by raccoon predation range from 40 to 100% nest destruction for Cape Sable, Florida (Davis and Whiting, 1977); Hutchinson

Island, Florida (Worth and Smith, 1976) and South Carolina beaches (Stancyk et al., 1980). At the major nesting beach at Cape Canaveral, Florida, as many as 90% of the natural nests are destroyed within 24 hours of deposition (Ehrhart, 1976). The estimates given for these areas represent nests totally destroyed and not overall mortality which may be much higher. These high rates of raccoon predation contrast with those surmised for the South Brevard nesting beach. Raccoon predation was judged superficially by Bjorndal et al. (1983) to be quite low, based on nightly turtle tagging efforts. They further speculated that because of this, the South Brevard nesting beach may produce more hatchling loggerheads than any other Florida beach.

South Brevard's current lack of high density development and vehicular beach traffic may also contribute to high reproductive success. This attribute is quickly waning, however, given the currently phenomenal rate of coastal development there. This condition warrants a rapid analysis of man's influence on the nesting beach while actions taken to curtail his effects are still possible.

The Recovery Plan for Marine Turtles (Hopkins and Richardson, 1984) stresses the necessity of monitoring levels of hatchling production, especially on densely nested beaches. Given the apparent importance of the South Brevard nesting beach, a study systematically quantifying its reproductive output was proposed. The primary objective of this study was to determine overall hatchling production for this beach by assessing the number and fate of the clutches deposited there. An additional objective was to identify factors which were significant causes of egg and hatchling mortality. A further objective was to suggest means by which those various biotic and abiotic factors could be mitigated.

There exists an implied potential for the production of over one million hatchling turtles per season from this South Brevard beach. This study sought to assess the extent to which this vast reproductive potential is actually realized.

METHODS

Study Area

The area of study was a previously delineated 21 km stretch of beach in south Brevard County, Florida (Figure 1), henceforth referred to as Melbourne Beach. The northern study area boundary was an arbitrary zero point, located exactly 5 km south of 5th Avenue in Indialantic, Florida. Sebastian Inlet State Recreation Area served as the opposing boundary, 21 km to the south. The study area was divided into 21, one kilometer sections which were identified by numbered stakes and permanent landmarks. Each of these one-kilometer areas will be referred to as sections, with section 1 beginning at the zero point and sections 2 through 21 extending southward. Unless otherwise stated, all research activities took place within these prescribed boundaries.

Melbourne Beach's physical attributes include a relatively sloped berm, coarsely grained sands often consisting of broken shell, a surf that breaks in close proximity to the beach, and most other general traits that characterize high energy beaches (Bascom, 1960). During the 1985 marine turtle nesting season, the profile of Melbourne Beach retained the effects of a severe storm that occurred in November of 1984. Evidence of erosion remained in the form of a steeply scarped foredune. By the beginning of the 1985 nesting season, sea rocket (Cakile edentula) had begun to pioneer the bare substrate at the base of

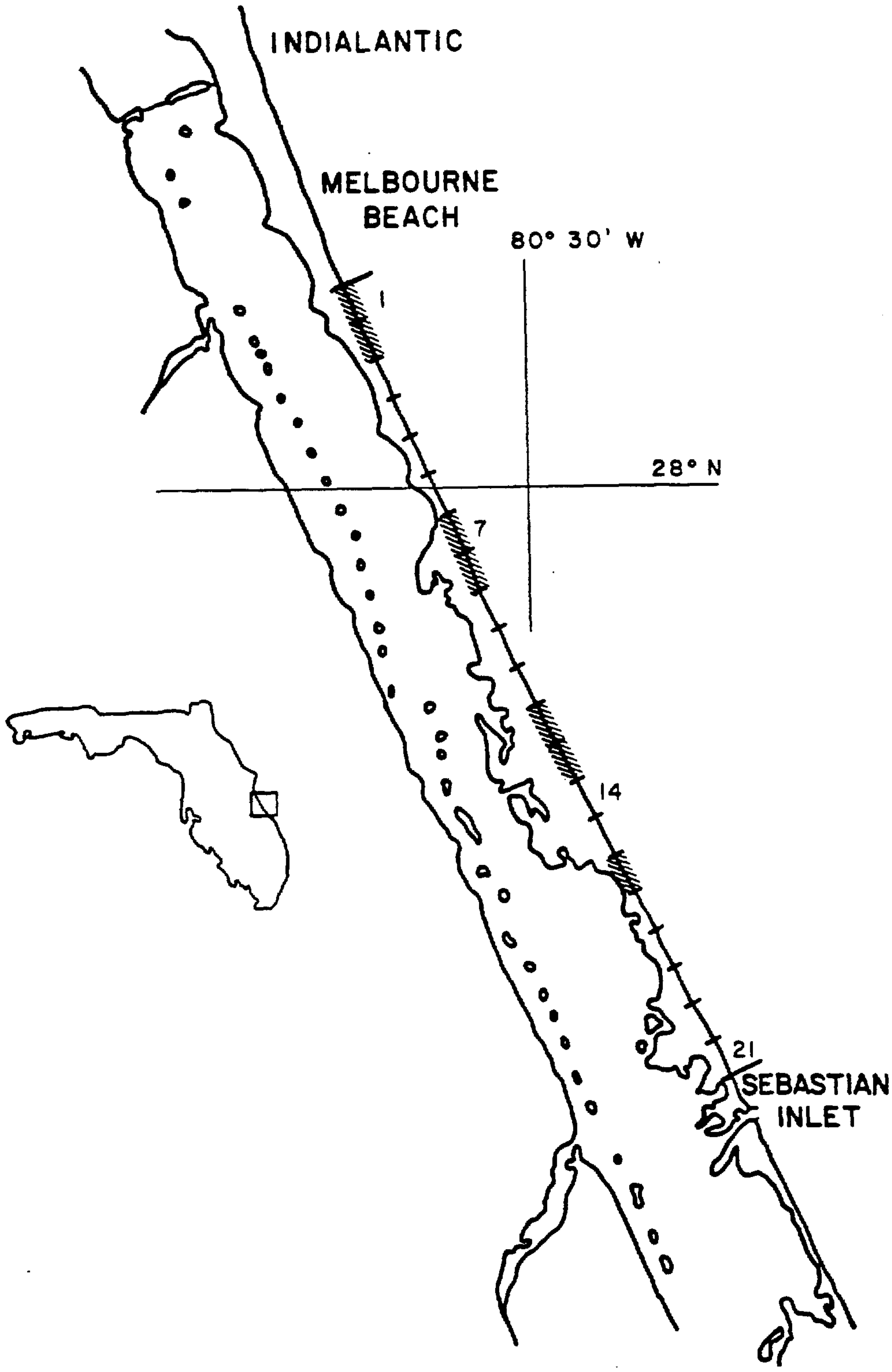


Figure 1. The 21 km Melbourne Beach study area in 1985. The shaded regions are areas of denser residential development. Numbered sections are one kilometer in length. The northernmost section (1) begins five kilometers south of 5th Avenue in Indialantic, Florida.

the foredune. Later in the summer, this area became sporadically sodded as precarious clumps of sea oats (Uniola paniculata) fell from the crests of the sandy cliffs and runners of beach morning-glory (Ipomoea pes-caprae) crept out onto the berm. By mid-summer, the base of the dune in certain sections had become sparsely vegetated, but the formidable dune escarpment continued to preclude any marine turtle nesting in the heavily vegetated portion of the dune.

The vast majority of beachfront properties along Melbourne Beach are privately owned. Four centers of residential development are indicated by Figure 1. This development consists primarily of single-family dwellings with scattered single or two-story motels. Multi-story condominiums exist mainly in the northernmost sections of the study area, though two rather large projects exist in sections 11 and 15, and additional buildings are currently under construction in sections 9, 12, and 15. No major "armoring" of the dune (seawalls, revetments) is currently present at Melbourne Beach. Even in areas where substantial residential development exists, the dune has been left relatively intact and some dune vegetation remains. Other areas, up to one kilometer in length, remain undeveloped, and the dune is naturally vegetated with saw palmetto (Seranoa repens).

Nesting Census

For an uncompromised assessment of marine turtle nesting within the 21 km study area, exhaustive daily surveys were conducted. These daily nesting surveys were initiated 13 May and continued until 12 September, 1985. Because of favorable beach conditions on 13 May, an additional 10 May survey and an 8 May aerial survey, an accurate assessment of nesting could be made from 8 to 12 May. This addition completed an unbroken interval spanning 8 May to 12 September, 1985.

Very little nesting was missed due to the 8 May starting date. This conclusion was based on interviews with beachfront residents and the first observation of hatchling emergence evidence, which placed the date of first significant nesting at 4-6 May. Nesting surveys were discontinued when two consecutive days of zero nesting were observed.

Each day's nesting survey was accomplished by traversing the 21 km study area by means of small, three-wheeled motorcycles. The survey was begun each day at about 0545 hrs, just after the cessation of most turtle nesting activity and before the resulting sign could be obscured. The numbers of nesting and non-nesting emergences for each 1 km section were recorded for each species. Characteristics of the tracks and nest sites were used to differentiate nesting and non-nesting emergences, and to make species identifications. Differences in gait and nesting behaviors which determine track and nest sign evidence are described by Bustard (1972).

Marking Sample Nests

To assess clutch and hatchling mortality, a representative sample of nests deposited within the study area were marked and followed throughout their incubation. A sampling method was employed that assured proper representation of the overall distribution of nesting within the study area. On randomly chosen nights, one to three investigators patrolled the study area on three-wheeled motorcycles. Starting points (north, middle, and south access sites) and starting directions (north or south) were chosen randomly prior to the beginning of each night's field work. Only nests of turtles encountered during the early stages of nesting behavior (emergence from surf, constructing the body pit or digging the egg chamber) were marked as sample nests. Turtles encountered during latter stages (oviposition, covering, returning) were generally ignored because of the difficulty in counting eggs already in the egg chamber. This method of sampling eliminated spatial and temporal bias in sample nest selection.

With a few exceptions noted below, clutches were counted and nests were marked at the time of deposition according to the following protocol.

1. Clutch size was determined by counting eggs as they fell into the egg chamber. Investigators caught each egg instantaneously with one hand and then let it pass into the egg chamber as it was recorded on a digital counter in the other hand.
2. The species of turtle, nest identification number, date and time of deposition, activity of the animal at discovery, and approximate location (to the nearest 0.1 km) were recorded.
3. For the purpose of relocating the clutch, the exact location of each egg chamber was determined by making a precise measurement to a numbered stake at the dune base and to any permanent landmarks. A 20 cm diameter aluminum disc was buried 0.5 m to the south of each nest to facilitate relocation (by the use of a metal detector) in the event that the stake was removed.
4. A monel metal tag was applied to the proximal trailing edge of the left front flipper on each turtle. These tags were provided by Dr. Archie Carr of the University of Florida and had a University of Florida return address engraved on them.

5. Using a graduated forestry caliper (straight line measurements) and a graduated metal tape (over curvature measurements), (standard) straight line and greatest (total) carapace length, straight line carapace width, curved carapace length and width, and maximum head width (Pritchard et al., 1983) were measured and recorded for each turtle. Indications of carapace and flipper injury and evidence of previous tags (calluses, tearouts) were also noted.
6. Each nest's position on the beach was measured in relation to nearness to vegetation, spring high tide mark, and dune escarpment base. Ghost crab burrows and obstructions in the egg chamber, height of the dune scarp and type of nearest vegetation were also noted.

A total of 100 loggerhead and 27 green turtle nests were marked and included in the sample. In order to obtain numbers of green turtle nests adequate for analysis, it was necessary to mark and use some without the benefit of observing the nesting female. In these cases, clutch size was determined by carefully excavating with nest within 12 hours of deposition. At that time, the eggs were counted and returned to their original positions within the egg chamber. Success among nests treated in this fashion was found not to differ from those nests whose clutches were counted during deposition. Green turtle sample nests, although most often chosen in a fashion dictated by the sampling protocol, were otherwise chosen randomly from nests discovered during the daily nesting surveys.

Two leatherback nests were marked as samples within the study area boundaries, although as noted for some green turtle nests, the adult female was not seen in either case. An additional leatherback nest was discovered about 1 km north of the study area and dangerously near the surf. It was relocated within the study area for convenience of observation.

Assessment of Sample Nest Success

As part of the clutch and hatchling survivorship assessment, all sample nests were observed each day during the nesting surveys for signs of depredation or other disturbances. Notes describing disturbances to sample nests were recorded in a daily log. When sample nests exhibited signs of a hatchling emergence, the sand immediately surrounding the emergence was smoothed, so that subsequent emergences could be discerned. Hatchling emergence sign was, in many cases, partially effaced by wind, rain, or tide. In those cases where hatchling tracks could be distinguished, the number of hatchlings leaving the nest was estimated. Tracks of predators, drag marks, evidence of hatchling disorientation, and dead or dying hatchlings in the vicinity of the emergence were noted.

When sample nests no longer displayed any sign of emergence activity, or at 60 days post-deposition, nests were excavated and their contents inventoried. From the exhumed nest contents, the following were determined: (1) The number of successfully hatched eggs; (2) the number and condition of live and dead hatchlings remaining in the nest; (3) the number and condition of hatchlings that had pipped the egg but had not successfully emerged from the shell; (4) the number, and ontological and physical condition of unhatched embryos; (5) the number of apparently infertile eggs and those for which no judgment about fertility could be made; and (6) evidence of subterranean perturbation or predation and the number of eggs affected.

To determine the modus operandi of subterranean ghost crab predation, several unmarked nests which displayed signs of obvious ghost crab damage (eggshells in the spoil of an accompanying crab burrow) were excavated. Samples of obviously depredated eggs were collected and cataloged, so that comparisons could be made with suspect eggs discovered in sample nests.

Four different measures of reproductive success were formulated to describe aspects of survivorship and productivity. Three of the measures of success are based on the fraction of eggs/hatchlings that attain certain developmental milestones. These milestones bound the period of marine turtle life history that begins with deposition as eggs and ends with submergence in the surf as hatchlings. These three measures of success (hatching success, emerging success, and approximate ocean-bound success) were calculated for each sample nest where such a determination was possible. An additional measure of success, emergence success (not to be confused with emerging success), was not calculated for each sample nest, but was instead, a single value based on all sample nests.

Definitions of the aforementioned measures of success are as follows.

Hatching success - The fraction of eggs which result in hatchlings that successfully extricate themselves from the eggshell, calculated as a percentage of yolked eggs within each clutch.

Emerging success - The fraction of eggs which result in hatchlings that successfully escape from the nest (i.e., reach the surface of the sand), calculated as a percentage of yolked eggs within each clutch.

Approximate ocean-bound success - The fraction of eggs which result in hatchlings that successfully enter the ocean, calculated as a percentage of yolked eggs within each clutch. This measure is termed an approximation, because it is based largely on circumstantial evidence of hatchling mortality en route from nest to surf.

Emergence success - The fraction of sample nests that result in at least some emergent hatchlings, calculated as a percentage of total sample nests for each species.

A number of important characteristics were recorded for each sample nest. The following is a list of characteristic definitions.

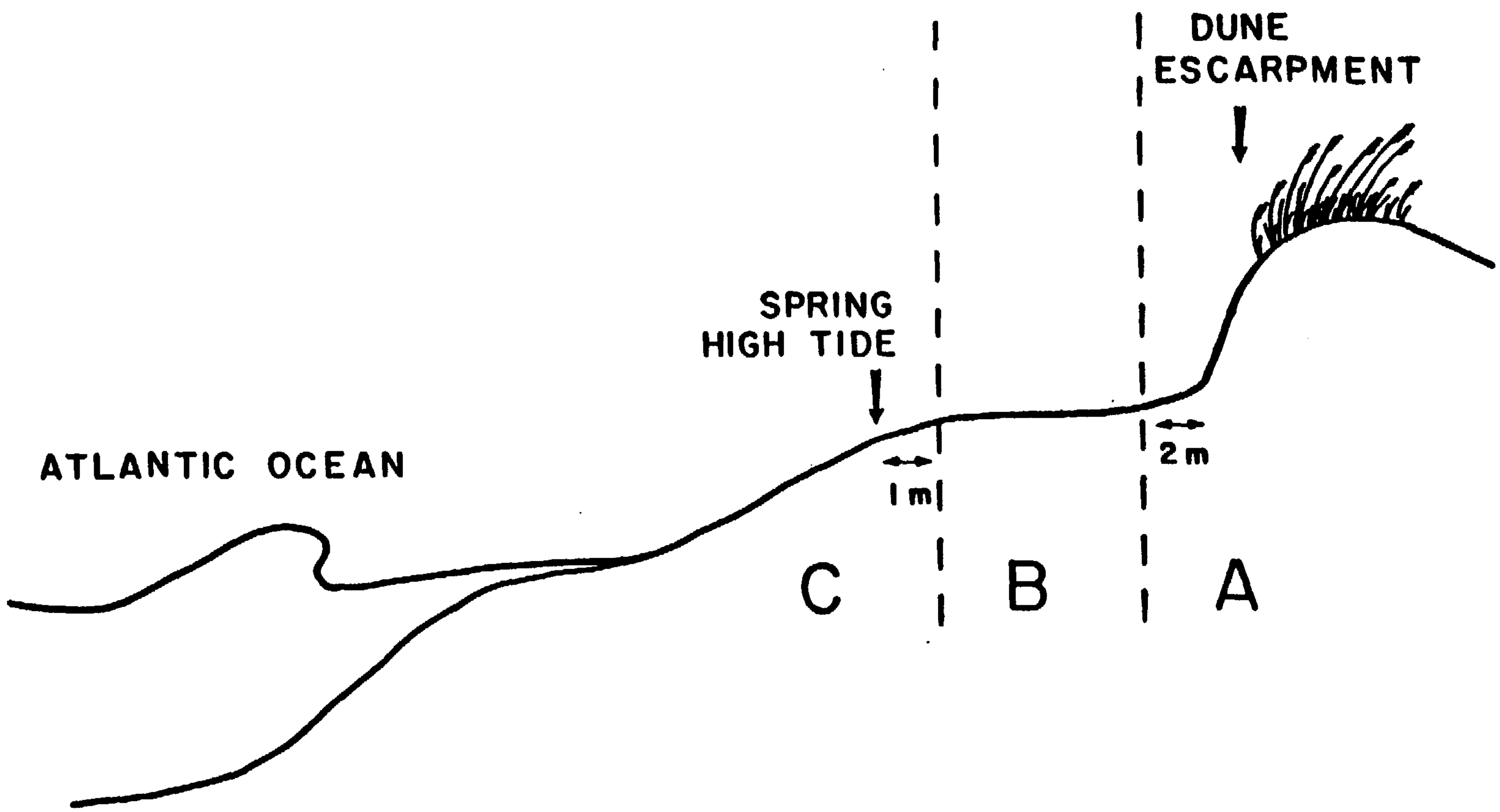
Deposition date - The date the clutch was deposited by the female turtle.

Incubation period - The period of time, beginning with the deposition date and ending with the date of the largest hatchling emergence. For clutches that had only small hatchling emergences, the period ended with the first hatchling emergence. When clutches emerged during daylight hours (most often following afternoon rainshowers), the final day of incubation was counted as one-half day.

Zone of deposition - The region of beach where a sample nest was deposited by the female turtle (Figure 2). Three arbitrary zones, each with boundaries parallel to the surf line, were established as convenient descriptive localities: zone A, within 2 m of the dune escarpment base; zone B, between the boundary of zone A and 1 m above the spring high-tide mark; zone C, below the lower boundary of zone B.

Disturbance - Any perturbation to the nest which causes mortality of eggs or hatchlings.

Figure 2. Melbourne Beach study area beach profile showing three arbitrarily delineated zones of deposition; A, B and C. Zone A lies within 2 m of the dune escarpment base; zone B lies between the boundary of zone A and 1 m above the spring high tide mark; and zone C lies seaward of the lower boundary of zone B.



Daily Qualitative and Quantitative Observations

A daily log of events was maintained throughout the 1985 nesting season. Detailed notes on meteorological conditions such as tides, precipitation, temperatures (air and surf) and surf and beach conditions were kept, in addition to notes on significant or unusual events pertaining to the nesting beach.

In addition to the sample nest assessment, a survey of the incidence of raccoon predation was carried out each day. During daily nesting surveys, the location, type, and extent of any depredated nests were noted in a daily log. Each incidence of raccoon predation was described using evidence within the nest (eggshells, embryos and other egg contents). These descriptions indicated whether the incident involved fresh nests (nests less than 24 hours old), nests in early incubation (containing eggs not near pipping), nests in late incubation or pre-emergence (containing term embryos or hatchlings), or post-emergence nests (containing only shells from emergent hatchlings). Observations were limited to days which offered favorable beach conditions for accurate sign interpretation.

As a relative measure of raccoon population density, the locations of all raccoon road kills occurring on Highway A1A were recorded from 10 May to 12 September, 1985. Highway A1A parallels the nesting beach study area on the west at a distance of approximately 100-150 meters.

Hatchling disorientation due to beachfront lighting was hypothesized to be a significant cause of post-emergence mortality. For this reason, an extensive survey of hatchling disorientation was undertaken. During daily nesting surveys, every observable hatchling emergence trace was tallied in a daily log. These emergences were described as being properly oriented or disoriented. Disorientations were further noted as being major (involving the majority of the clutch) or minor (involving the minority).

To supplement information gathered from sample nests on post-emergence hatchling loss, 48 non-disoriented and 18 disoriented clutches were examined for ghost crab predation. Assessments of post-emergence mortality were based on a combination of sign evidence (drag marks and dead hatchlings) and ghost crab burrow excavation.

Assimilation of Data Incidental to Nightly Excursions

During nightly excursions to mark sample nests, many turtles whose nests were not marked were encountered. These turtles were consistently checked for previous tags and tag scars. As often as possible, measurements were obtained on those turtles previously tagged, so that data concerning growth, nesting interval, and interim travel could be acquired.

Statistical Analysis

Comparisons and correlations between data were made using primarily nonparametric statistical tests (Ott, 1984). Although no test for normality was attempted, the distribution of most data (especially reproductive success data) did not approximate a normal curve. Small sub-sample sizes made the application of statistical tests invalid in very few cases. Individual statistical tests are mentioned where appropriate in the results section of this report.

RESULTS

Nesting Census

The first survey of nesting activity within the study area was conducted on 8 May. By this date, it was apparent that some loggerhead nesting had already occurred. Initial nesting of loggerheads on Melbourne Beach in 1985 was believed to have occurred between 4 and 6 May. This conclusion was based, in part, on interviews with beachfront residents. The first recorded loggerhead hatchling emergence, observed 30 June, reinforced this conclusion, assuming a 55-57 day incubation period (a range encompassing values recorded for early season clutches). Loggerhead nesting continued until 12 September, after which nesting was considered insignificant. One loggerhead nest was observed as late as 3 October. Loggerhead nesting occurred exclusively during the hours of darkness, except for two reported afternoon nestings. These afternoon nestings each occurred during daily high-tide periods. Initial green turtle nesting occurred on 31 May and continued until 10 September. Commencement of nesting varied by one month between loggerheads and green turtles (figures 3 and 4). These different dates of initial nesting manifested a distinct difference between the two species in the time of the season at which the heaviest concentration of nests were active. The greatest concentration of loggerhead nests were incubating on 22 July (63%), while for green turtles, the greatest portion of nests were incubating on 19 August (75%).

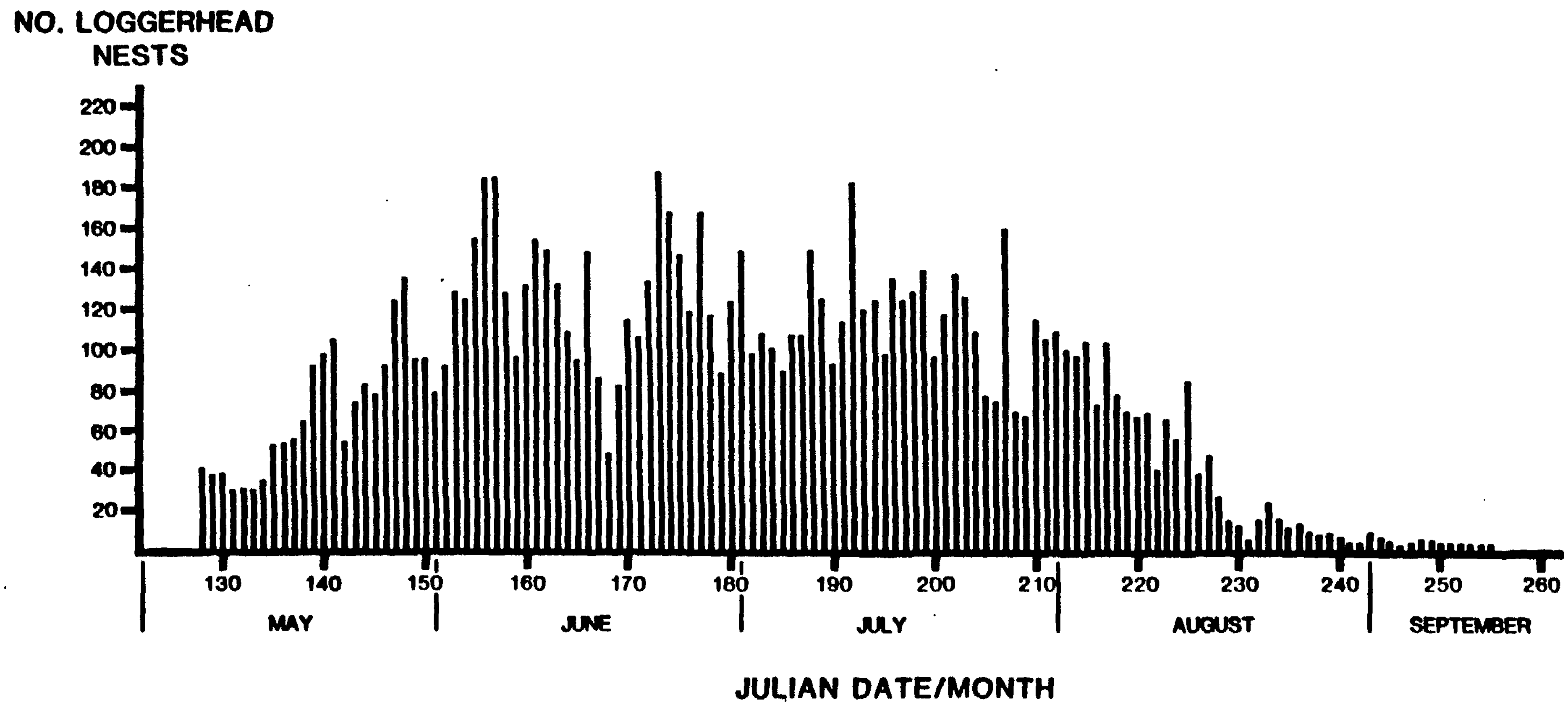


Figure 3. Temporal distribution of loggerhead (Caretta caretta) nesting within the Melbourne Beach study area in 1985.

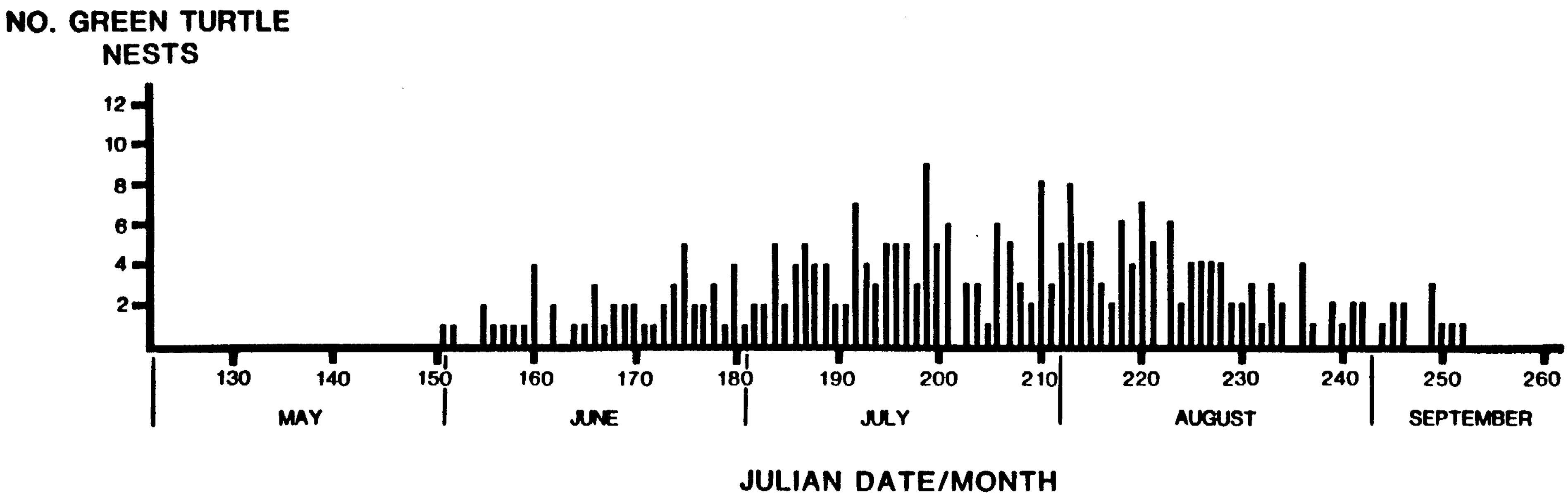


Figure 4. Temporal distribution of green turtle (Chelonia mydas) nesting within the Melbourne Beach study area in 1985.

Temporal nesting distributions of loggerheads (Figure 3) and green turtles (Figure 4) indicate that nesting in both species reaches a plateau rather than a single peak of activity. Overlapping cycles of various periodicities may or may not be present in these nesting distributions. The considerable daily variation in nesting numbers, with some exceptions, did not correspond with changes in any measured variable. These daily oscellations did not appear synchronous between species. Sharp fluctuations in surf temperature are known to influence nesting activity (Williams-Walls et al., 1983); however, no such fluctuations of sufficient amplitude to affect nesting occurred off Melbourne Beach in 1985. Tropical Storm Bob passed the study area briefly on 24 July and did cause a temporary drop in loggerhead nesting activity, probably due to rough surf conditions (Figure 3).

The total census of nesting activity within the study area revealed 10,240 loggerhead, 281 green turtle, and two leatherback clutches deposited in 1985. These counts of loggerhead and green turtle nests exceed all estimates from previous surveys on this same stretch of beach (Ehrhart and Raymond, ms.). Average loggerhead nesting density within the study area was 490 nests per kilometer.

The number of green turtle nests recorded within the study area in 1985 surpassed estimates from previous seasons by over five-fold. Green turtle nesting densities averaged 13.4 nests per kilometer and were as high as 30 nests per kilometer within some parts of the study area in 1985.

Leatherback nesting within the study area was minor. Because leatherbacks are known to nest in April on Florida Beaches (Fletemeyer, 1984), some nesting may have gone unobserved because surveys were not begun until 8 May. One leatherback nest, in addition to the two discovered within the study area, was deposited just beyond the northern boundary. The dates of these three leatherback nestings were 14 May, 11 June, and 20 June.

Figure 5 depicts loggerhead nesting by 1 km sections. Northern and southern sections of the study area displayed consistently lower nesting densities compared to central sections. No definite correlation could be made between this spatial nesting distribution and any measured or observed attribute of the beach. Loggerhead nesting densities by section ranged from 209 to 666 nests per kilometer (Table 1).

Figure 6 represents green turtle nesting by section. Areas of nesting preference differed greatly between loggerheads and green turtles. The greatest densities of green turtle nesting occurred in the southern sections of the study area. General attributes of these southern sections included sparser development, less nightly human activity, and less beachfront lighting than the northern sections. As a general observation, lighted areas of the beach were typically devoid of green turtle nesting, while darker areas, especially areas shrouded by trees, enjoyed extensive green turtle nesting. Green turtle nesting densities within the study area ranged from 3 to 30 nests per kilometer (Table 1).

Crawls from female turtles that advanced beyond the recent high tide mark but did not result in a successful nesting were considered non-nesting emergences. Table 1 lists numbers of non-nesting emergences for each species by section. Forty-four percent of all loggerhead emergences and 31 percent of all green turtle emergences resulted in abandoned attempts. This difference was found to be significant (bino-

Figure 5. Horizontal nesting distribution of loggerheads (*Caretta caretta*) within the Melbourne Beach study area in 1985. Section one is located five kilometers south of 5th Avenue in Indialantic, Florida.

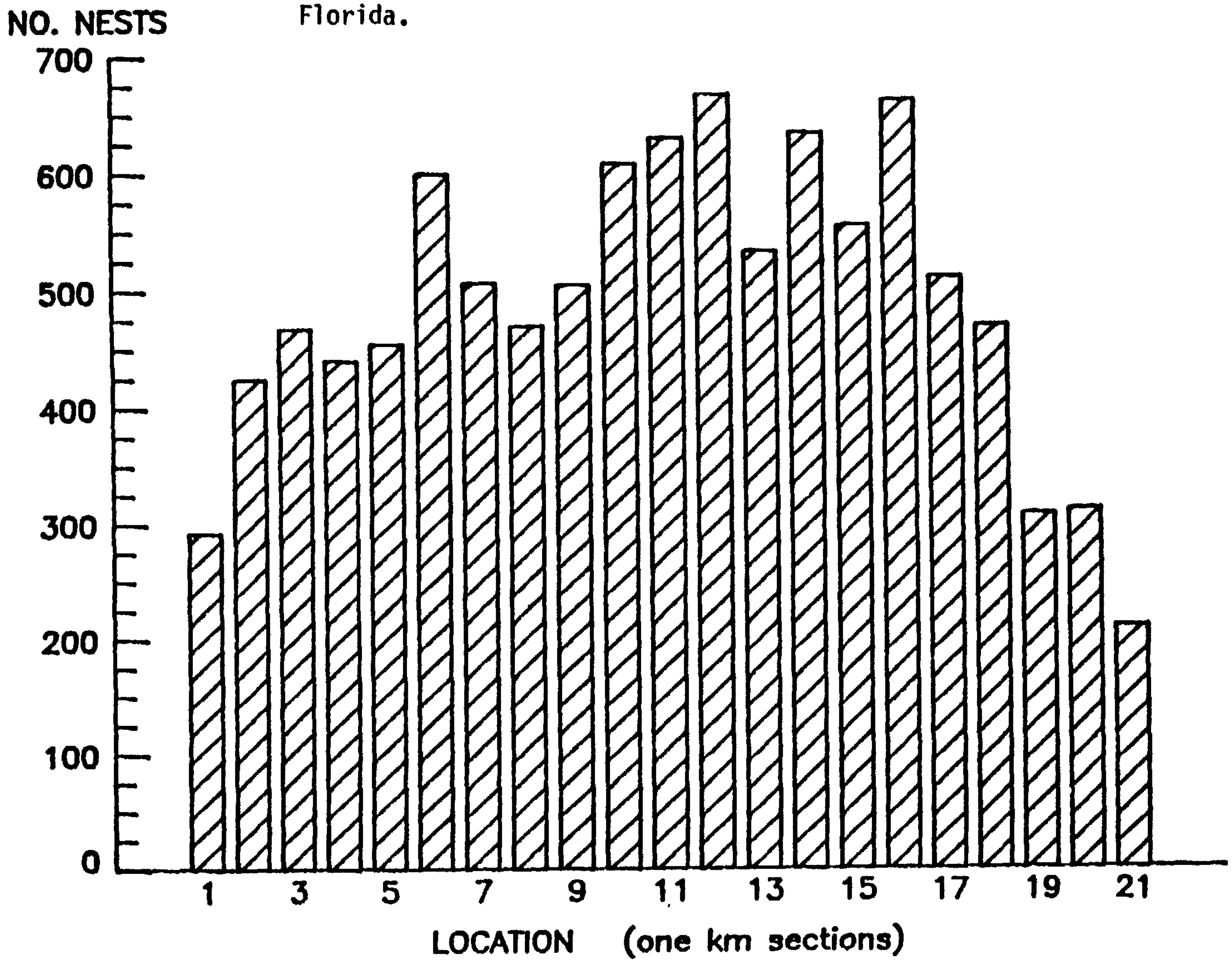


Figure 6. Horizontal nesting distribution of green turtles (<u>Chelonia mydas</u>) within the Melbourne Beach study area in 1985. Section one is located five kilometers south of 5th Avenue in Indialantic, Florida.

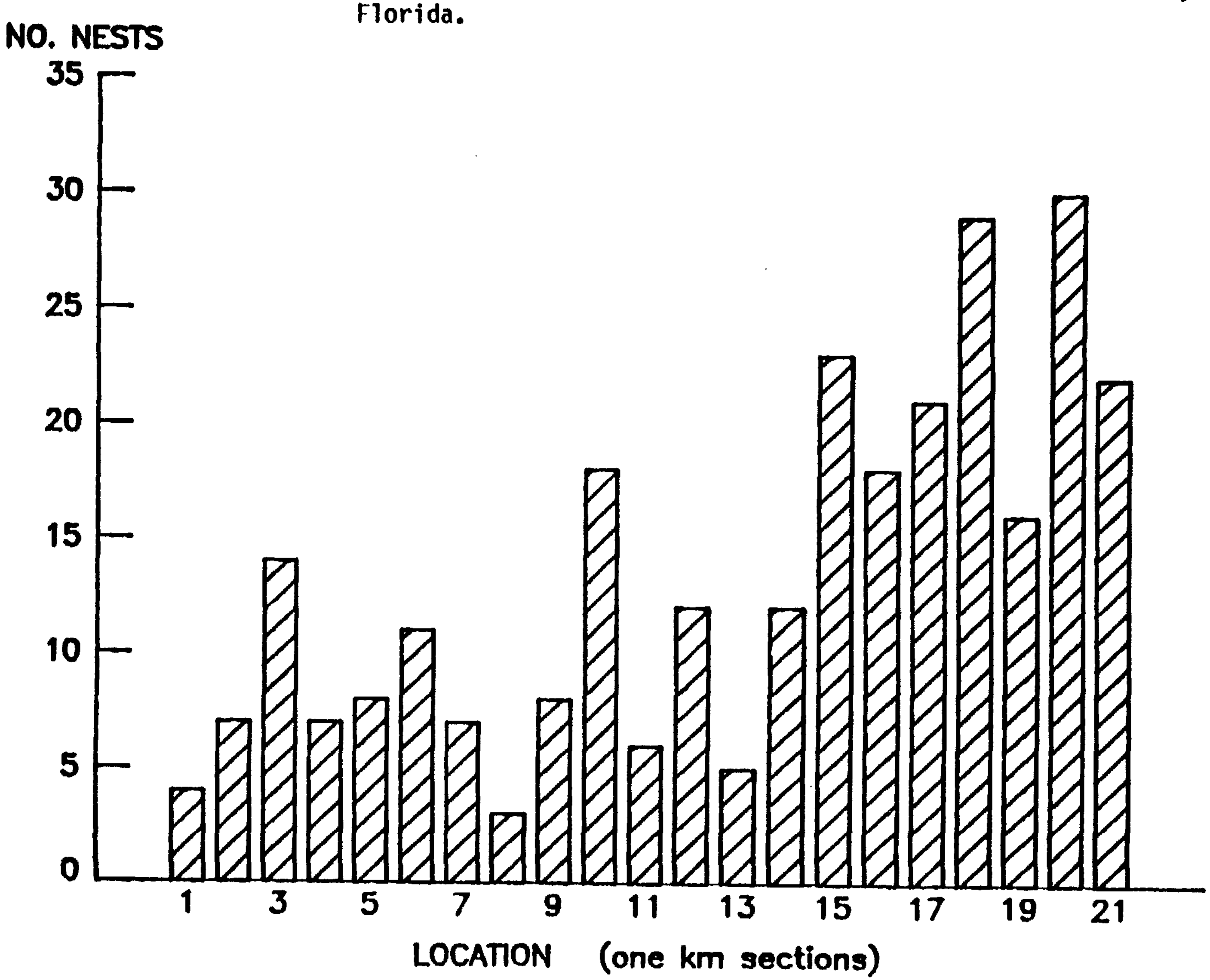


TABLE 1

Nesting and non-nesting emergences of loggerheads (Caretta caretta) and green turtles (Chelonia mydas) counted during a census of 21 km of beach in south Brevard Co., Florida, 1985. Locations are specified as one km sections, the northernmost section (1) beginning five km south of 5th Avenue, Indialantic, Florida.

	Loggerhead Emergences		Green Turtle Emergences	
Location	Nesting	Non-nesting	Nesting	Non-nesting
1	292	178	4	3
2	424	371	7	6
3	467	378	14	4
4	440	398	7	0
5	454	407	8	6
6	599	582	11	9
7	506	495	7	5
8	469	573	3	0
9	504	639	8	3
10	607	591	18	6
11	629	428	6	3
12	666	458	12	4
13	532	413	5	2
14	633	311	12	6
15	554	289	23	11
16	661	369	18	6
17	510	268	21	10
18	468	215	29	8
19	306	194	16	9
20	310	184	30	19
21	209	130	22	12
Total	10,240	7,871	281	124

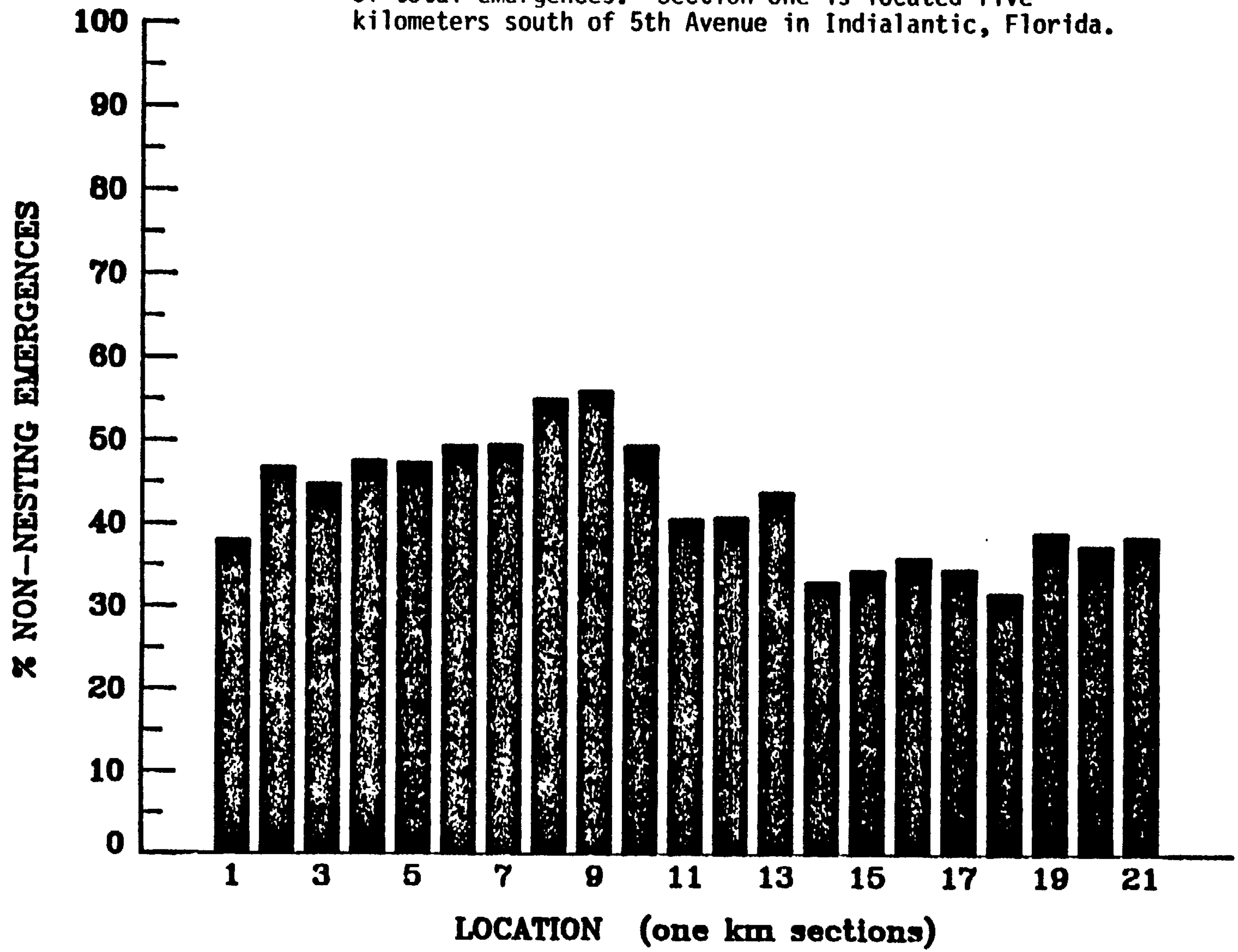
mial two-population test, $P < 0.05$). Loggerhead non-nesting emergences are depicted by section in Figure 7. Loggerheads emerging in the northern sections of the study area appeared to abandon nesting attempts more frequently than loggerheads emerging farther south.

Analysis of Initial Sample Nest Data

Appendix tables 1 and 2 contain respectively, measured morphological characteristics of loggerheads and green turtles encountered during this study. Turtles whose nests were incorporated as sample nests are included with their identifying sample nest numbers. Means, standard deviations, and ranges are included for all morphological characters. Some turtles listed in these tables were encountered twice within the nesting season; in these cases, only initial measurements were used in calculating means. One green turtle with a grotesquely malformed (kyphotic) carapace was also excluded from these calculations.

Sample nests were categorized as having been deposited within three specified zones, A, B, and C (Figure 2). Due to a sharply scarped dune profile caused by a severe storm in November of 1984, nesting was, for the most part, restricted to an area seaward of the primary dune face. Despite this restriction, distinct variation in vertical nest site choice was observed, both within and between species (Appendix tables 3 and 4). On the average, green turtles nested higher on the beach than did loggerheads. The majority of loggerheads nested within zone B, while most green turtles nested within zone A. The mean distance measured from clutch to dune base was 6.8 m ($SD = 4.6$ m, $n = 100$) for loggerhead and 1.9 m ($SD = 2.5$ m, $n = 27$) for green turtle sample nests. A student's t-test revealed significant differences between these means ($P < 0.05$). Variations in these vertical distributions of loggerhead

Figure 7. Horizontal distribution of loggerhead (Caretta caretta) non-nesting emergences in 1985, expressed as a percentage of total emergences. Section one is located five kilometers south of 5th Avenue in Indialantic, Florida.



and green turtle nests did not appear to correspond to cycles of spring and neap tides. Likewise, there was no apparent trend toward higher nest placement later in the season. There was, however, some relationship apparent between daily tide conditions and loggerhead nest placement. Based on subjective observations, loggerheads emerging during daily high-tide periods deposited clutches closer to the dune than those emerging during low tide.

Clutch sizes for loggerhead and green turtle sample nests are listed in Appendix tables 5 and 6. One green turtle clutch was excluded from the mean. The turtle that deposited this clutch was frightened by the bright lights of an onlooker and appeared to have aborted midway through oviposition without attempting to cover her clutch. Three leatherback clutches contained a mean of 94 yolked eggs (SD = 7.0) and 26 yolkless eggs (SD = 9.4). Mean clutch size for loggerheads was found to be 116 eggs. Seven clutches of green turtle eggs were excavated and given to Ross Witham (Florida DNR) for incorporation into a head-starting program. With the inclusion of these clutches, mean green turtle clutch size was 145 eggs (SD = 21.7, n = 33). Clutch sizes of green turtles and loggerheads were found to differ significantly (Table 2).

Loggerhead clutch size was found to be negatively correlated with advancing dates of deposition (Table 3). No significant correlation was found, however, between green turtle clutch size and date of deposition (Table 4).

Mean straight line carapace length (CLSL) measurements differed significantly between loggerheads and green turtles (Table 2). The

TABLE 2

A table of Wilcoxon Rank-sum Test results for comparing measurements of loggerhead (*Caretta caretta*) and green turtle (*Chelonia mydas*) nests/nesting females sampled from 21 km of beach in south Brevard Co., Florida, 1985. Abbreviations: IP, incubation period; CLSL, carapace length straight line of nesting female; ES, emerging success of clutch; CS, clutch size; DFD, distance the clutch was deposited from the dune escarpment base.

	LOGGERHEAD			GREEN TURTLE			Significance
Measurement	N	$\bar{x}$	Mean Rank	N	$\bar{x}$	Mean Rank	One-tailed(P)
IP*	67	53.1 da	42.3	20	54.0 da	49.7	NS
CLSL	119	92.2 cm	50.1	27	101.5 cm	100.6	<0.0001
ES	97	55.7 %	61.8	25	56.6 %	60.5	NS
ES*	85	63.6 %	54.1	24	58.8 %	48.7	NS
CS	100	116.2	51.9	33	144.7	99.8	<0.0001
DFD	118	6.8 m	83.1	27	1.9 m	28.8	<0.0001

*only measurements from nests not affected by a September storm tested

TABLE 3

A table of correlations between sets of variables tested by Spearman's Rank Order Correlation Coefficient (Rsp). The data source is a group of loggerhead (Caretta caretta) nests/nesting females sampled from 21 km of beach in south Brevard Co., Florida, 1985. Abbreviations: CLSL, carapace length straight line of nesting female; IP, incubation period; ES, emerging success of clutch; DD, date clutch was deposited; DO, date female observed nesting; CS, clutch size.

Variables Tested	n Pairs	Rsp	Significance One-tailed (P)
CLSL/CS	97	0.71	<0.0001
CLSL/DO	97	-0.23	0.013
CLSL/ES	97	0.10	NS
CLSL/ES*	83	-0.02	NS
IP/CS*	67	0.17	NS
IP/DD*	67	-0.37	0.0015
IP/ES*	67	-0.05	NS
ES/CS	97	0.12	NS
ES/CS*	83	0.05	NS
ES/DD	97	-0.28	0.004
ES/DD*	83	0.02	NS
CS/DD	97	-0.37	<0.0002

*only variables from nests not affected by a September storm tested.

finding that nesting loggerheads were, on the average, smaller than Florida green turtles agreed with the conclusions of Ehrhart (1979).

A significant positive correlation was found between body size of nesting loggerheads (CLSL) and their respective clutch sizes (Table 3, Figure 8). Ehrhart (1979) observed a similar relationship between body size and clutch size of nesting loggerheads.

A significant negative correlation was found between the CLSL of nesting loggerheads and the Julian date on which they were observed nesting (Table 3). These findings indicate that larger loggerheads were nesting earlier in the season than smaller ones. This condition probably explains the observed diminution in clutch size with advancing date of deposition.

As for loggerheads, a significant positive correlation was found between green turtle CLSL and clutch size (Table 4, Figure 9), but no correlation was detected between CLSL and nesting dates of females (Table 4).

Incubation Period

The determination of incubation period relied upon favorable beach conditions and could not be made accurately for all sample clutches. The conclusion of incubation was marked by the first substantial emergence of hatchlings from the nest. The emergence of marine turtle hatchlings is thought to be in response to declining ambient temperatures (Bustard, 1972). Though most hatchling emergences from sample nests occurred at night, a significant number occurred during afternoon rain showers (10 percent of all loggerhead and green turtle sample nests). Evidence indicating this phenomenon was the presence of a depression resulting from the collapse of the egg chamber with hatchling

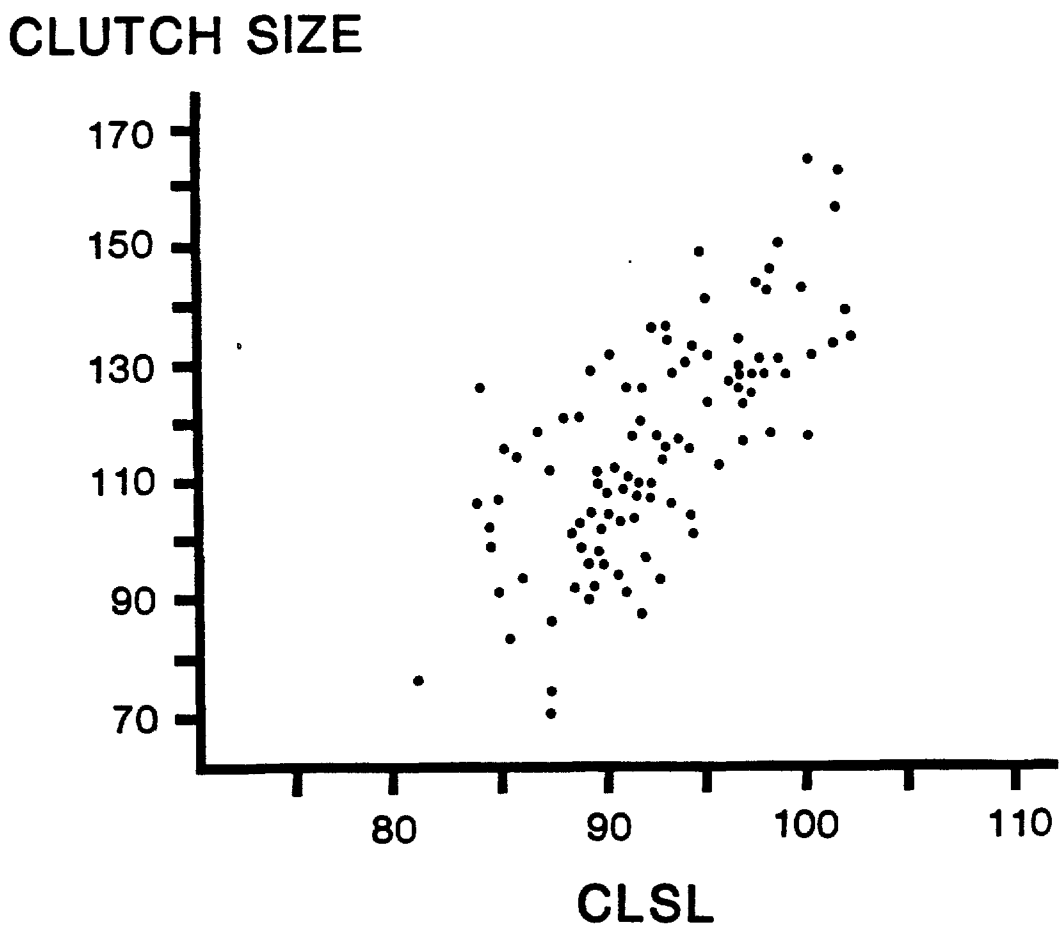


Figure 8. A scatter-graph showing the relationship between loggerhead (<u>Caretta caretta</u>) clutch size (no. of eggs) and nesting female straight-line carapace length (CLSL) in centimeters.

TABLE 4

A table of correlations between sets of variables tested by Spearman's Rank Order Correlation Coefficient (Rsp). The data source is a group of green turtle (Chelonia mydas) nests/nesting females sampled from 21 km of beach in south Brevard Co., Florida, 1985. Abbreviations: CLSL, carapace length straight line of nesting female; IP, incubation period: ES, emerging success of clutch; DD, date clutch was deposited; DO, date female observed nesting; CS, clutch size.

Variables Tested	n Pairs	Rsp	Significance One-tailed (P)
CLSL/CS	17	0.40	0.05
CLSL/DO	18	-0.25	NS
CLSL/ES	16	0.26	NS
IP/CS	19	-0.28	NS
IP/DD	20	0.28	NS
IP/ES	20	0.04	NS
ES/CS	16	0.26	NS
ES/DD	25	-0.09	NS
CS/DD	26	0.08	NS

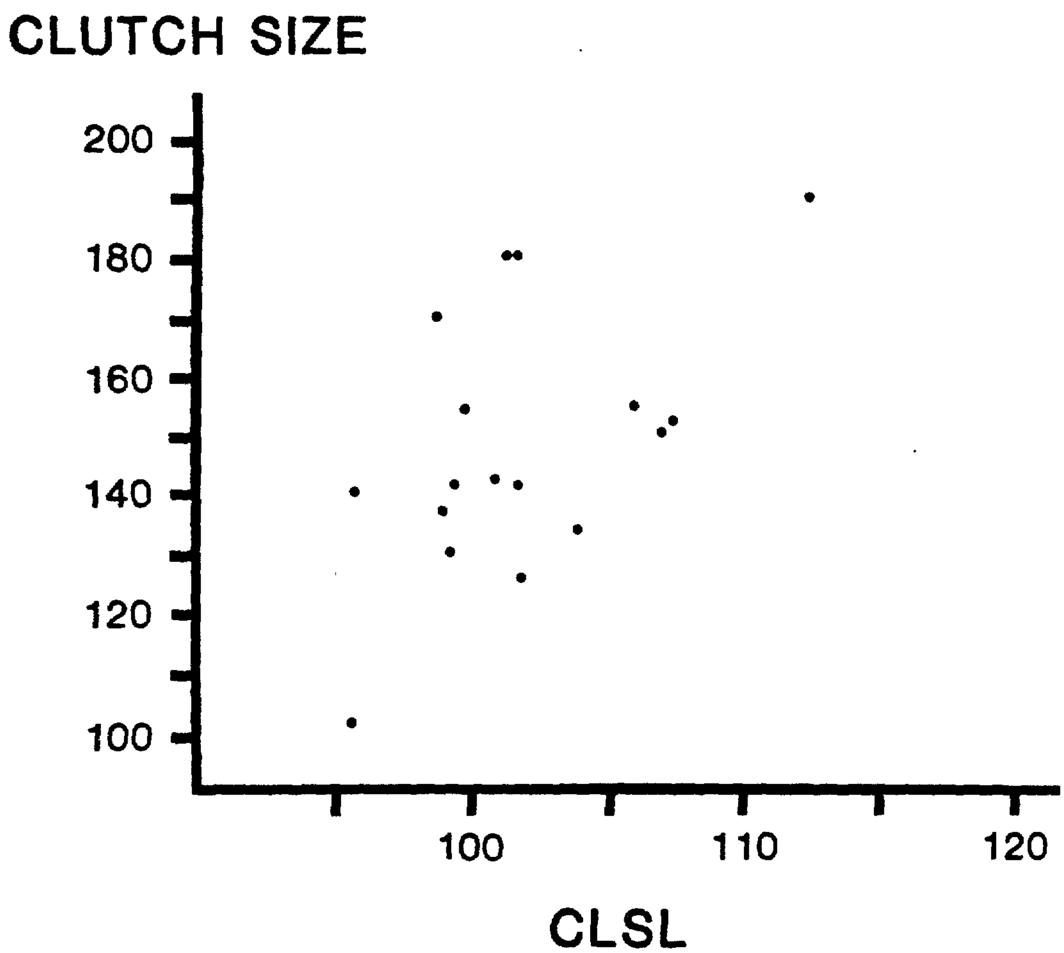


Figure 9. A scatter-graph showing the relationship between green turtle (Chelonia mydas) clutch size (no. of eggs) and nesting female straight-line carapace length (CLSL) in centimeters.

tracks leading from this depression effaced by rain. When showers were known to have occurred during daylight hours and not at night, this evidence was assumed to indicate a daylight emergence.

Sixteen percent of all loggerhead and sixty-five percent of all green turtle sample clutches exhibited multiple hatchling emergences from the same clutch (modes = one and two emergences per clutch, respectively). Mean incubation period was 53 days for loggerhead and 54 days for green turtle sample nests (Appendix tables 3 and 4).

No significant correlation was found between incubation period and clutch size of either species (tables 3 and 4). Only loggerhead sample clutches displayed a significant negative correlation between incubation period and date of deposition (Table 3). Because incubation period is known to shorten with increasing ambient temperatures (Bustard, 1972), these findings are consistent with sand temperature data taken within the nesting season. Average mid-berm sand temperatures at a depth of 40 cm were found to be 28.0, 28.5, 30.0, and 29.0 C for the months of May, June, July, and August, respectively. Late-season sand temperature probably did not influence the correlation of incubation period with date of deposition, because many late-season sample nests were destroyed by a September storm. Differences in loggerhead incubation period between three zones of deposition were not found to be significant (Table 5). The small number of green turtle sample nests within zones B and C made a similar analysis invalid. Shaded and heavily vegetated nesting sites, known to influence incubation periods negatively (Fowler, 1979), were generally absent within the study area.

TABLE 5

A table of Kruskal-Wallis one-way ANOVA results for comparing incubation periods of sample loggerhead (*Caretta caretta*) clutches from three zones of deposition. Zone A is located nearest the dune escarpment, Zone C nearest the surf and Zone B between zones A and C.

Zone of Deposition	No. Nests	$\bar{x}$ Incubation Period (days)	Mean Rank
A	12	52.7	30.9
B	40	53.0	32.3
C	15	53.8	41.1

H = 2.63

P = NS

Analysis of Reproductive Success

Measures of Success

Values indicating reproductive success were calculated separately for sample nests not affected by a severe mid-September storm (non-storm nests). The focus of the analysis of reproductive success centers on these nests. The rationale for this is presented in the discussion section of this report. An analysis of clutch mortality caused by this storm is given later in this section.

Values for three defined measures of reproductive success are listed for loggerheads (Appendix Table 5) and green turtles (Appendix Table 6). Some sample clutches could not be relocated and were excluded from analysis. Overall, reproductive success was judged quite high for both species. Mean hatching and emerging success values for non-storm loggerhead sample nests were 66 and 64 percent. These same measures calculated for undisturbed loggerhead sample nests were 84 and 83 percent.

Mean hatching and emerging success of non-storm green turtle sample nests were 63 and 59 percent. These values did not differ significantly from those of loggerhead sample nests (Table 2).

Sample size for the calculation of mean approximate ocean-bound success for both species was very limited, because assessment of this measure was dependent on beach conditions which were not always ideal. Assessments of approximate ocean-bound success were not made under less-than-ideal conditions, but regardless of beach conditions, clutches that were totally destroyed due to disturbances were known to have a success of zero percent. For this reason, the mean values for approximate ocean-bound success are probably artificially depressed. A more accurate measure of post-emergence hatchling mortality is given later in this section.

Three leatherback clutches marked within the study area failed to hatch. No embryological development was detected within any of the eggs. All eggs were entire, non-addled, had intact vitelline membranes and were probably infertile.

The proportion of loggerhead sample nests which produced some emergent hatchlings (emergence success) was 85 percent (Table 6). Green turtle emergence success was 80 percent. Undisturbed loggerhead and green turtle nests had emergence success values of 95 and 100 percent.

Loggerhead emerging success was found to differ ($P = 0.06$) between three zones of nest deposition (Table 7a). The results of a Wilcoxon Rank-Sum Test revealed that central values of loggerhead emerging success did not differ significantly between zones A and C (Table 7b). Zone B, however, was found to contain nests which displayed higher central values of emerging success than the more seaward zone (C) and the zone closer to the dune vegetation (A).

No significant correlation was detected between emerging success of loggerhead and green turtle sample nests and clutch size, date of deposition, incubation period, and CLSL of the corresponding nesting female (tables 3 and 4). A negative correlation between emerging success and date of deposition indicated in Table 3 includes late season nests destroyed by the September storm.

An opportunity was afforded to compare values of emerging success between subsequent nests of three different loggerheads (Appendix Table 5). Success was high for both clutches of one female (nest no.s

TABLE 6

Emergence success (ESS) of loggerhead (*Caretta caretta*) and green turtle (*Chelonia mydas*) sample nests marked during the 1985 nesting season in south Brevard County, Florida. Emergence success is defined in the report text.

	Undisturbed Nests		Nests Not Affected By September Storm		Total Nests	
	ESS(%)	n	ESS(%)	n	ESS(%)	n
Loggerhead	95.3	43	84.7	83	74.2	97
Green turtle	100.0	12	80.0	24	80.0	25

TABLE 7a

Tables of Kruskal-Wallis one-way ANOVA results for comparing measures of emerging success of sample loggerhead (Caretta caretta) clutches from three zones of deposition. Zone A is located nearest the dune escarpment, zone C nearest the surf, and zone B between zones A and C.

ALL SAMPLE NESTS

Zone of Deposition	No. Nests	$\bar{x}$ Emerging Success (%)	Mean Rank
A	15	52.7	43.2
B	50	64.7	54.9
C	31	42.3	40.8

$H = 5.67$
$P < 0.06$

NESTS NOT AFFECTED BY SEPTEMBER STORM

Zone of Deposition	No. Nests	$\bar{x}$ Emerging Success (%)	Mean Rank
A	14	56.5	33.2
B	43	74.0	47.3
C	25	52.4	36.1

$H = 5.58$

$P = 0.06$

TABLE 7b

Tables of Wilcoxon Rank-Sum Test results for comparing measures of emerging success of sample loggerhead (Caretta caretta) clutches from three zones of deposition. Central values of emerging success for zones with the same Roman numeral grouping are not significantly different at the P = 0.05 level.

ALL SAMPLE NESTS

Grouping	Zone of Deposition	$\bar{x}$ Emerging Success (%)
I	A	52.7
II	B	64.7
I	C	42.3

NESTS NOT AFFECTED BY SEPTEMBER STORM

Grouping	Zone of Deposition	$\bar{x}$ Emerging Success (%)
I	A	56.5
II	B	74.0
I	C	52.4

8 and 9), but later clutches of the two others were destroyed by the September storm. Subsequent clutch sizes were lower in all cases.

Factors Affecting Reproductive Success of Sample Nests

Descriptive fates of loggerhead clutches and those of constituent eggs are listed in tables 8 and 9. Fates of green turtle clutches and eggs are given in tables 10 and 11. Pie charts depicting clutch and egg fates of sample nests are provided for loggerheads (figures 10 and 11) and green turtles (figures 12 and 13). The following accounts of success-limiting factors reinforce their depictions in these tables and figures.

The breakage of eggs by the depositing female was rare, occurring in only two green turtle nests and involving a total of five eggs. One instance of a nesting loggerhead uncovering a green turtle sample clutch was recorded, but no damage was sustained by the clutch. Within 24 hours, however, the green turtle clutch was subjected to extensive predation by raccoons. Though the uncovering of the nest was probably a contributing cause, the fate of this green turtle sample nest was categorized as having been destroyed by raccoons.

Sample clutches exposed to the affects of surf wash and erosion were usually destroyed completely. The category "damaged by surf" includes those clutches that were completely washed away or had development arrested due to drowning. Among non-storm nests, surf damage played a relatively minor role in destroying 3 percent of all loggerhead sample clutches. Only one non-storm green turtle sample clutch was destroyed by the surf.

Surf damage played a major role in destroying sample nests subjected to the severe September storm. The observation that only those

TABLE 8

Descriptive fates of loggerhead (Caretta caretta) sample clutches marked during the 1985 nesting season in south Brevard County, Florida.

	No. of Nests	
	All	Non-storm*
Undisturbed	43	43
Emerged	41	41
Did not emerge	2	2
Disturbed	54	54
Emerged	31	31
Ghost crab depredated	27	27
Raccoon depredated	1	1
Root infiltration	3	3
Affected by surf	0	0
Affected by sand accretion	0	0
Did not emerge	23	11
Ghost crab depredated	0	0
Raccoon depredated	6	6
Root infiltration	0	0
Affected by surf	12	3
Affected by sand accretion	5	2
Total	97	85

*Only those nests not affected by a September storm

TABLE 9

Descriptive fates of loggerhead (*Caretta caretta*) eggs constituting clutches from sample nests marked during the 1985 nesting season in south Brevard County, Florida.

	No. of Eggs	
	All	Non-storm*
Unhatched	4711	3299
Destroyed by surf	1374	370
Destroyed by sand accretion	542	212
Destroyed by ghost crabs	293	246
Destroyed by raccoons	772	772
Destroyed by plant roots	275	275
No apparent development	466	462
Development arrested with no apparent physical disturbance	255	245
Contents putrefied with no apparent physical disturbance	600	585
Hatchling died while pipping	134	132
Hatched	6554	6439
Hatchling died in nest (straggler)	88	85
Depredated in nest by ghost crabs	30	30
Depredated in nest by raccoons	105	105
Emerged from nest	6331	6219
Total	11,265	9738

*Only those eggs from clutches not affected by a September storm

Table 10

Descriptive fates of green turtle (Chelonia mydas) sample clutches marked during the 1985 nesting season in south Brevard County, Florida.

	No. of Nests	
	All	Non-storm*
Undisturbed	12	12
Emerged	12	12
Did not emerge	0	0
Disturbed	13	13
Emerged	8	8
Ghost crab depredated	5	5
Raccoon depredated	0	0
Plant root infiltration	2	2
Affected by surf	1	0
Emergence artificially obstructed	0	0
Did not emerge	5	5
Ghost crab depredated	1	1
Raccoon depredated	1	1
Plant root infiltration	1	1
Affected by surf	1	1
Emergence artificially obstructed	1	1
Total	25	24

*Only those nests not affected by a September storm

TABLE 11

Descriptive fates of green turtle (<u>Chelonia</u> <u>mydas</u>) eggs constituting clutches from sample nests marked during the 1985 nesting season in south Brevard County, Florida.

	No. of Eggs	
	All	Non-storm*
Unhatched	1246	1122
Broken by nesting female	5	5
Destroyed by surf	142	142
Destroyed by ghost crabs	181	181
Destroyed by raccoons	131	131
Destroyed by plant roots	276	276
No apparent development	67	67
Development arrested with no apparent physical disturbance	123	89
Contents putrefied with no apparent physical disturbance	270	190
Hatchling died while pipping	51	41
Hatched	2340	2309
Hatchling died in nest (straggler)	21	21
Drowned in nest due to high surf	26	0
Emergence blocked	136	136
Emerged from nest	2157	2152
Total	3586	3431

*Only those eggs from clutches not affected by a September storm

Figure 10. Clutch fates of loggerhead (Caretta caretta) sample nests marked within the Melbourne Beach study area in 1985.

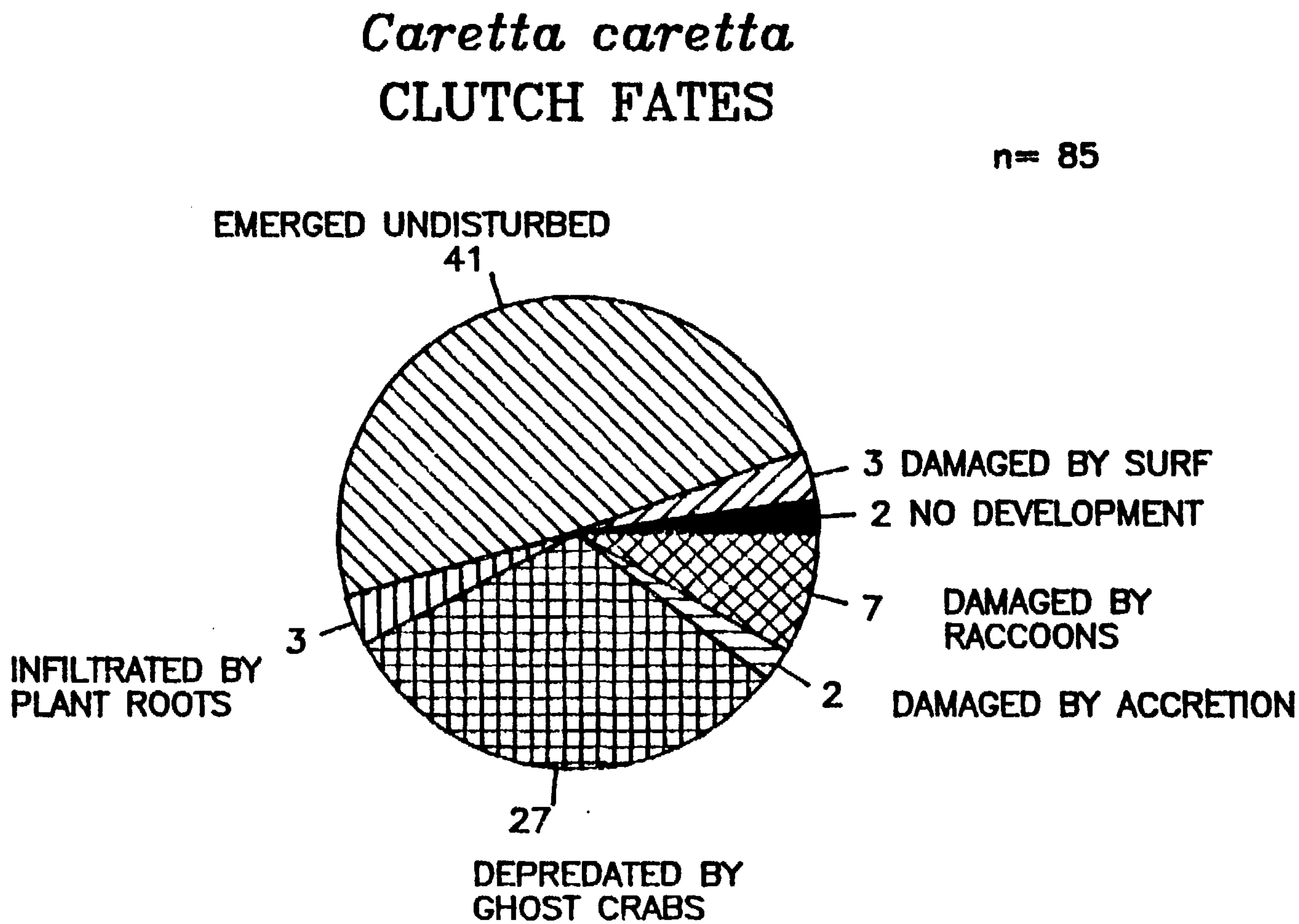


Figure 11. Fates of consitutent eggs from loggerhead (Caretta caretta) sample nests marked within the Melbourne Beach study area in 1985.

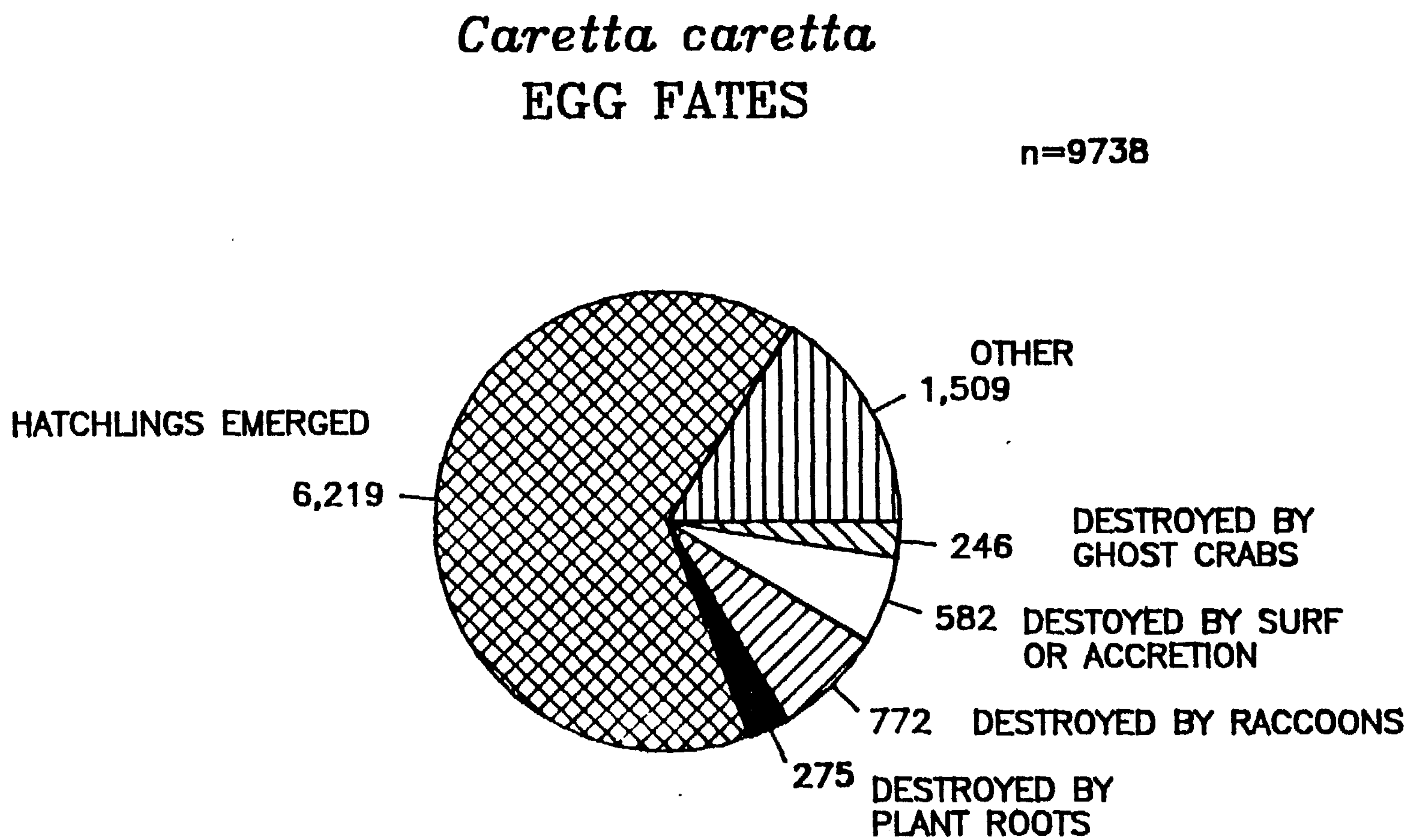


Figure 12. Clutch fates of green turtle (Chelonia mydas) sample nests marked within the Melbourne Beach study area in 1985.

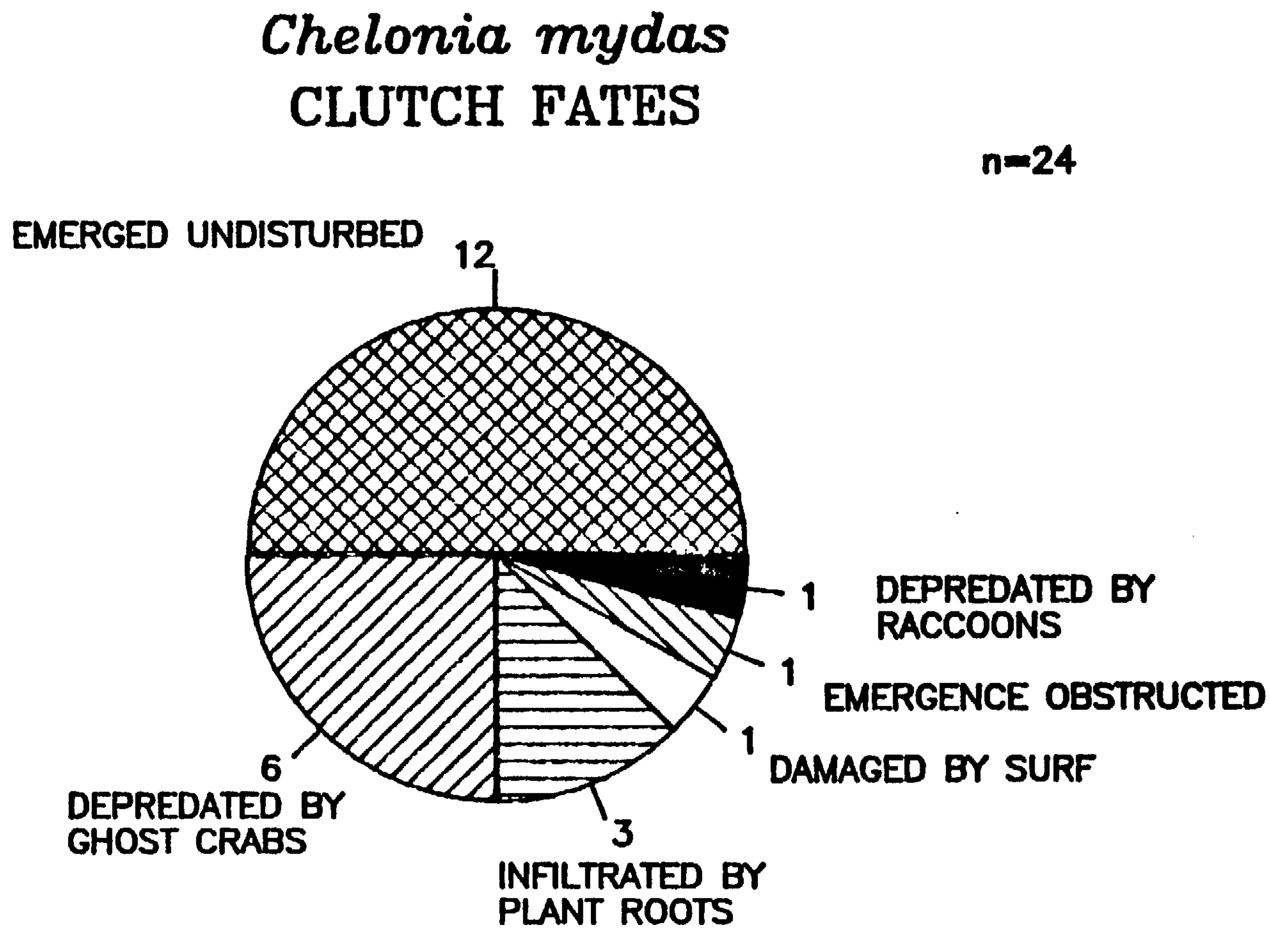
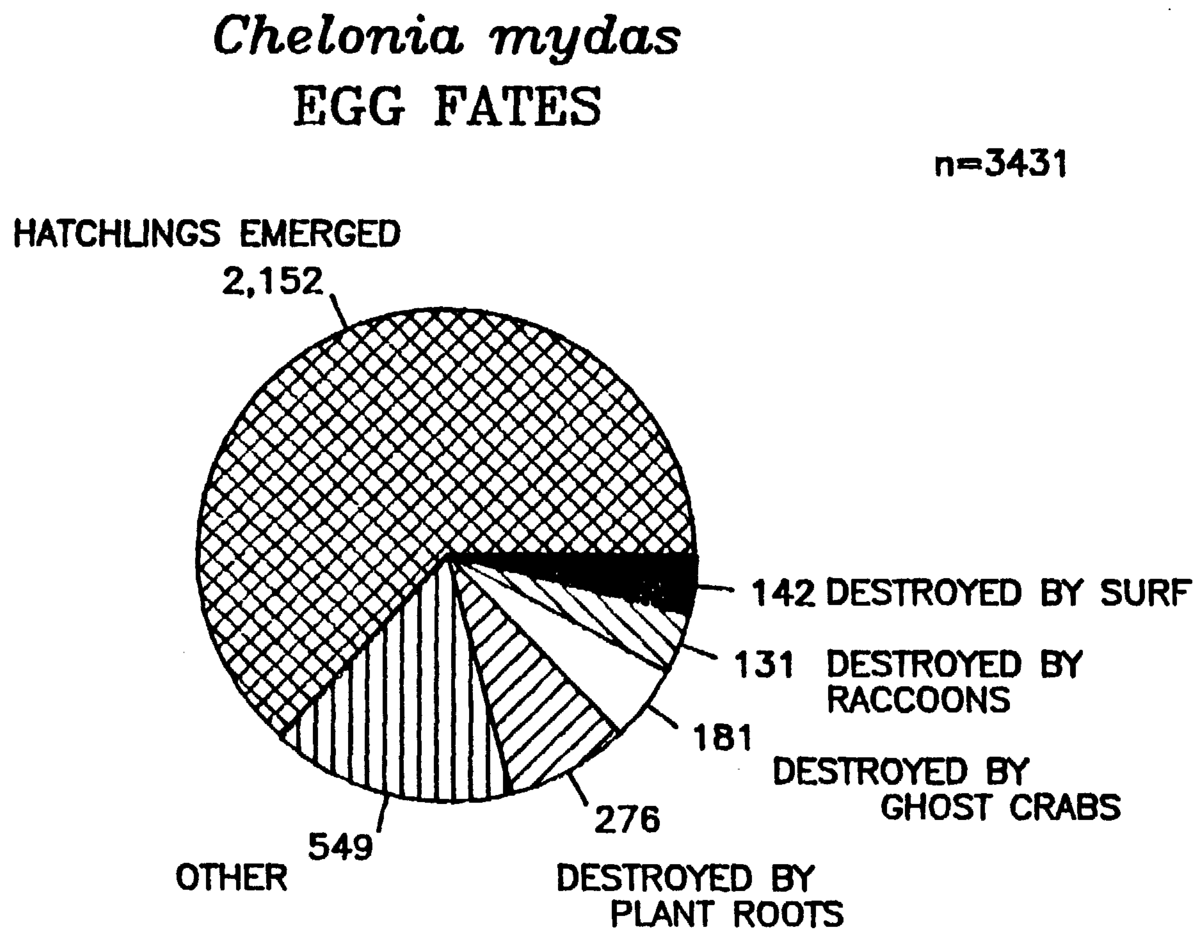


Figure 13. Fates of constituent eggs from green turtle (Chelonia mydas) sample nests marked within the Melbourne Beach study area in 1985.



nests lower on the beach suffered arrested embryological development attested that surf wash, not rain, was the primary cause of failure for storm-affected nests. One storm-damaged nest contained hatchlings that had apparently drowned during their ascent to emerge.

Accretion of sand over loggerhead clutches was an unusually destructive occurrence. All affected nests were totally destroyed with embryological development arrested very early or midway through incubation. The amount of sand accreted could, in all cases, be determined by the depth of the aluminum disc used to mark the nest. Up to 75 cm of sand was found to have been deposited over destroyed clutches. The ultimate cause of failure in these clutches was most likely suffocation. The zone of accretion was at the center of the berm, just above the spring high-tide mark. A substantial amount of accretion seemed to have been associated with the September storm, though this accretion occurred much higher on the berm. No green turtle nests were affected by this phenomenon.

The major predator of eggs within the study area was the raccoon (<u>Procyon lotor</u>). Raccoons were very efficient in completely consuming or destroying nearly all the clutches they depredated. Seven percent of all loggerhead sample clutches were depredated by raccoons. All these clutches were totally destroyed, except for a clutch depredated just pre-emergence from which several hatchlings escaped. The only green turtle sample clutch depredated by raccoons was one previously mentioned that had been uncovered by a nesting loggerhead. This clutch was completely destroyed.

Nests depredated by raccoons were not inventoried until a time suitable for the incubation of any remaining eggs had passed. In all cases, eggs remaining in the nest were found to be addled due to contact with the contents of other eggs which had been broken.

All but one sample nest depredated by raccoons was done so between 20 and 40 days post-deposition. This was surprising, inasmuch as during this period, most apparent visual and olfactory cues had been effaced.

Predation by ghost crabs (Ocypode quadrata) was common among loggerhead and green turtle clutches. Ghost crabs invaded a substantial fraction of both species' clutches, yet destroyed only a small percentage of eggs. Thirty-two percent of all loggerhead and 25 percent of all green turtle sample nests were invaded by ghost crabs; however, only 2 and 5 percent of the constituent loggerhead and green turtle eggs were destroyed. These figures of egg damage include several instances where ghost crabs caused substantial secondary damage. As observed in raccoon depredated nests, eggs adjacent to other broken ones were often addled. Although differences exist in ghost crab predation rates between the two species, they are not significant (binomial two-population test, $P < 0.05$). Ghost crabs were also known to have taken hatchlings from pre-emergence clutches. This rate for loggerheads was 0.3 percent. While this value is probably underestimated slightly, it is also quite insignificant.

Ghost crabs were the sole predator of post-emergence hatchlings from sample nests. Data from evidence of post-emergence predation were pooled with other random observations and are discussed later in this section.

A curious form of "predation" affecting sample nests was the destructive invasion of clutches by plant roots. Plants involved were primarily beach morning-glory vine (Ipomoea pes-caprae) and in a single case, sea oats (Uniola paniculata). Incidents of plant root invasion were too infrequent to statistically ascertain differences in rates between species. It does seem, however, that green turtles suffered a greater clutch invasion rate (12%) and egg destruction rate (8%) than did loggerheads (3% of clutches and eggs invaded and destroyed).

For a substantial number of sample nest eggs, embryological development was arrested with no apparent major physical disturbance. Other eggs gave the appearance of being infertile. Because no microscopic examination of each egg was attempted and the fertility of eggs destroyed by predators was unknown, no conclusions specifically quantifying fertility were made. Observations of eggs known to have resulted in some embryological development, however, make the assessment of minimum fertility rates valid. Minimum fertility rates were 70 percent for loggerheads and 71 percent for green turtles. Seemingly infertile eggs, putrified or addled eggs, and eggs which were arrested during development made up 13 percent and 10 percent of all loggerhead and green turtle eggs.

Recognizable teratological deformities of loggerhead and green turtle embryos are presented in Table 12. Most deformities were manifested in white, late developing fetuses as described by Caldwell (1959a). As he observed and as McGehee (1979) also observed, no single clutch had a preponderance of deformed individuals. All deformities mentioned were major ones, primarily of the cephalic region. One clearly dicephalous green turtle hatchling was found.

One percent of all loggerhead and green turtle eggs resulted in fully-formed hatchlings that pipped their eggs but could not successfully extricate themselves from their shells. About 0.9 and 0.6 percent

TABLE 12

A summary of teratological deformities observed in nest-trapped hatchlings and term embryos from sample nests of marine turtles marked during the 1985 nesting season in south Brevard County, Florida.

	Loggerhead (Caretta caretta)		Green Turtle (Chelonia Mydas)	
	No. Individuals	No. Nests	No. Individuals	No. Nests
Hatchlings	4	4 of 97	3	3 of 25
Term Embryos	13	10 of 97	8	4 of 25

of all loggerhead and green turtle eggs resulted in hatchlings that extricated their shells but did not emerge from the nest. Some of these hatchlings displayed carapace or flipper deformities and are included in Table 12. Live hatchlings remaining in the nest are known to be unable to emerge without the group effort provided by their siblings (Carr and Hirth, 1961). Although designated as dead, these live nest-trapped hatchlings were released into the surf when found.

Some mortality incurred by sample nests could be directly or indirectly attributed to humans. One loggerhead nest was apparently subjected to the damaging effects of a four-wheeled vehicle prior to being depredated by raccoons. Although uncovering the clutch likely led to an enhanced probability of depredation, direct damage caused by the vehicle was unknown.

One green turtle nest, rescued from a predictable fate, is categorized under "obstructed emergence" in tables 10 and 11. A sizable load of Casuarina logs was piled over the clutch inadvertently, in an attempt by the beachfront property owners to stabilize the dune. Concluding that the clutch would have been lost without intervention, a portion of the debris was removed so that the clutch could emerge. The frequency and extent of such illegal dune reconstruction practices within the study area assured that the designation of this clutch as destroyed would not be misrepresentative.

Disorientation by artificial beachfront lighting was a major cause of post-emergence hatchling mortality. Data concerning disorientation rates of sample nests were pooled with random observations of natural emergences and are discussed later in this section.

Marine turtle nests incubating within the study area suffered considerable damage due to a severe storm which lingered from 15 to 20 September. Evidence from sample nests quantifying the rate of destruction was reinforced by observations of randomly marked natural nests. The effects of storm-generated erosion were monitored relative to the placement of these nests. Three of four green turtle sample nests incubating at the onset of the storm survived while only two of fourteen loggerhead nests did. These rates closely matched those estimated from observations of the randomly marked nests. Nests impacted by the storm's effect were typically destroyed completely while unimpacted nests displayed relatively normal success. At the storm's onset, 53 percent of all green turtle nests were still incubating, while only 23 percent of all loggerhead nests were (based on known temporal nesting distributions). Taking into account the number of nests present and the ratio of destruction for each species, an estimate of storm-related mortality was calculated. Overall mortality this September storm was about 13 percent of all green turtle and 19 percent of all loggerhead clutches.

Two tropical storms, Bob (24 July) and Elena (1 September), passed but did not linger near the study area and caused little or no significant damage to marine turtle nests. The effects of Hurricane Gloria (26 September) were felt only moderately within the study area, and it is doubtful whether any nests not already destroyed by the previous storm were affected.

Analysis of Daily Quantitative and Qualitative Observations

Mortality Influenced by Numbers of Nesting Females

Clutches destroyed by other nesting females were observed and tallied during daily nesting surveys. One case of a leatherback disturbing a loggerhead clutch, nine cases of loggerheads disturbing loggerhead clutches, three cases of green turtles disturbing loggerhead clutches and one case of a loggerhead disturbing a green turtle clutch were noted. Most of these clutches suffered subsequent depredation by raccoons, ghost crabs and/or fish crows (Corvus ossifragus). These tallies probably underrepresent somewhat the actual frequency of events.

Ghost Crab Predation

Outwardly visible signs of subterranean ghost crab predation (broken shells near burrow spoils) were obviously underrepresentative. Discernment of spatial patterns in ghost crab predation, therefore, was limited to systematic observations involving burrow placement. Fifty-eight observations were made for each of three substrate conditions: fresh loggerhead nests, old loggerhead nests, and undisturbed beach. An analysis of these observations is presented in Table 13. There was a significantly greater probability of encountering ghost crab burrows in fresh loggerhead nests than in old nests or in randomly-chosen undisturbed beach plots. Surprisingly, there was also a significantly greater proportion of ghost crab burrows in undisturbed beach than in old nests. Casual observations of areas of beach with fresh shovel-disturbed sand similarly indicated that ghost crabs preferred this freshly-disturbed sand to undisturbed surrounding beach.

Ghost crabs were found to be the only major predator of post-emergence hatchlings. This predation is discussed under the division on post-emergence mortality.

Raccoon Predation

Conclusions on the nature and extent of raccoon predation on marine

TABLE 13

Occurrences of ghost crab (*Ocypode quadrata*) burrows within randomly chosen 1m² quadrats at various locations. The study was carried out within 21 km of beach in south Brevard County, Florida on 29 May, 1985. Proportions were compared, using a binomial two-population test.

1 - Random, above high tide mark

2 - Fresh loggerhead nest

3 - Loggerhead nest two or more days old

	Quadrat Location		
Burrows Present	1	2	3
Yes	18	26	10
No	40	32	48
Total n	58	58	58
π	0.31	0.45	0.17

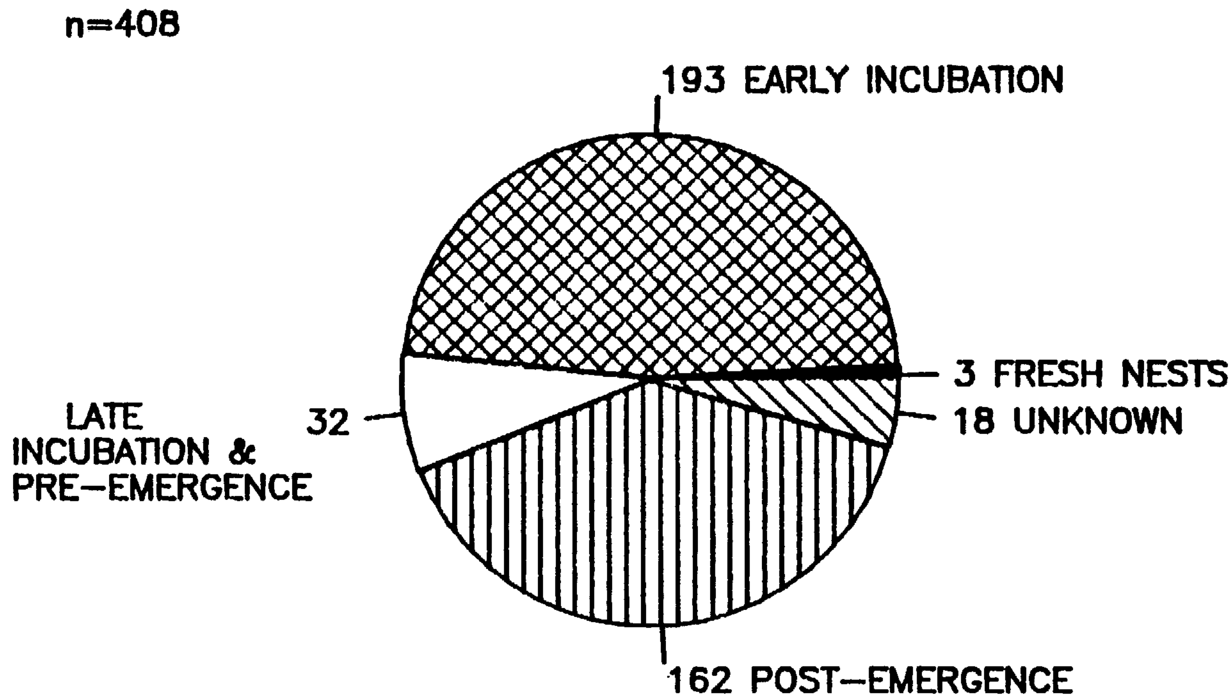
Ha	Test Statistic	Significance (P)
$\pi 1 > \pi 3$	2.8	0.003
$\pi 2 > \pi 3$	4.2	< 0.001
$\pi 2 > \pi 1$	2.1	0.02

turtle clutches within the study area were based on 408 observations of raccoon-disturbed nests. Disturbances to nests were judged by outwardly visible signs to have occurred either within 24 hours (fresh), before pipping (early incubation), after pipping (late incubation), or after hatchlings had already left the nest (post-emergence). Two categories, early and late incubation, were known to overlap somewhat, because of difficulties in discerning sign. The proportions of clutches disturbed during these incubation milestones are represented in Figure 14. Clearly, a negligible percentage of nests were disturbed by raccoons while they were still fresh. Strangely, the vast majority of destroyed clutches (~ 78%) were disturbed during early incubation, when most visual and olfactory cues have been effaced. These data correspond to findings from carefully-monitored sample nests. About 21 percent of all clutches that were destroyed were disturbed during late incubation or just pre-emergence, when olfactory cues from pipping hatchlings are present. These olfactory cues appear to have lingered long enough to prompt raccoons to dig up post-emergence nests from which hatchlings had already escaped. These cases constituted 40 percent of all disturbances and probably resulted in little mortality to hatchlings.

Raccoons were observed frequently to have capitalized on disturbances to nests created by extraneous sources. Three nests uncovered by vehicular traffic and five nests uncovered by nesting turtles were found to have been subsequently depredated by raccoons.

The temporal distribution of disturbances to nests caused by raccoons is compared to the temporal distribution of loggerhead nesting activity in Figure 15. Raccoons did not begin to fully exploit the beach until half of the nesting season had passed. Hopkins and Murphy

Figure 14. Marine turtle clutches depredated by raccoons during specific milestones of incubation. Events were tallied during daily surveys within the Melbourne Beach study area in 1985.



(1980), and Gallagher et al. (1972) also found raccoon predation to intensify later in the nesting season; however, this pattern is greatly exaggerated on Melbourne Beach due to an uncommon lack of fresh nest predation.

The spatial distribution of nest disturbances by raccoons is represented in Figure 16. Three sections in the southern portion of the study area clearly had substantially elevated levels of raccoon predation, compared to the surrounding sections. These three sections (17, 18, and 19) contained 63 percent of all the observed incidents. In Figure 16, relative raccoon population density throughout the study area is represented by the frequency of road-kills occurring along highway A1A. The distribution of road-kills appears to exhibit no correspondence with the distribution of predation.

Minor Forms of Predation

Ants (Formicidae) were a commonly observed secondary predator to previously disturbed clutches, but probably initiated little damage by themselves.

Fish crows were the primary avian predator of eggs and hatchlings. Some egg predation may have been initiated by fish crows, though most often they appeared to have simply shared in the spoils of nests opened by raccoons. Crows, being efficient scavengers, seemed to play a major role in removing dead and dying hatchlings that remained on the beach due to disorientation by beachfront lighting. Laughing gulls (*Larus atricilla*) were observed on two occasions to possess live and dead hatchlings, though the area and manner of predation were not known.

Domestic dogs were common within the study area, though their presence on the beach was prohibited by a county ordinance. Dogs dug

Figure 15. The relationship between the temporal distributions of loggerhead nesting and raccoon predation on marine turtle clutches within the Melbourne Beach study area in 1985.

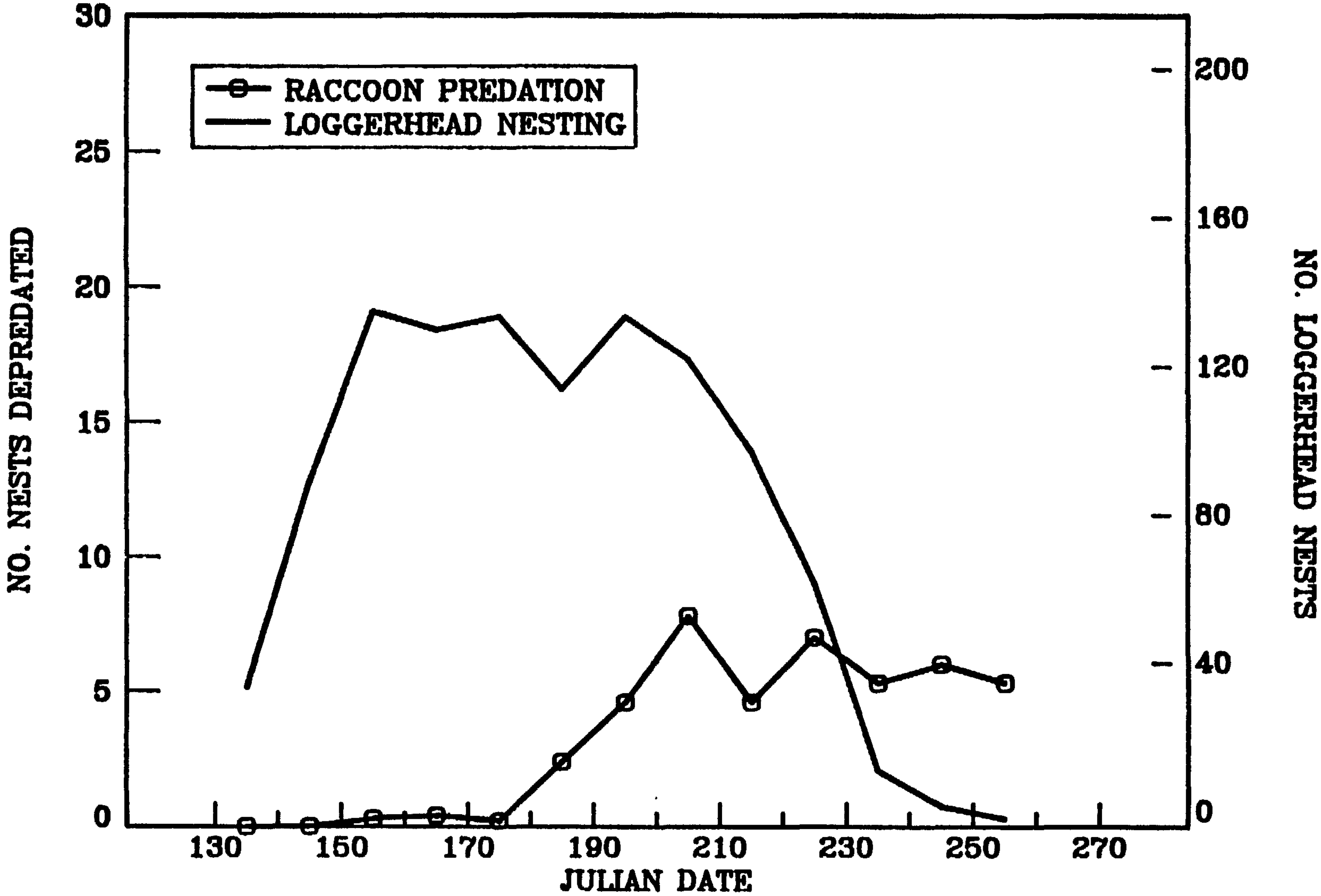
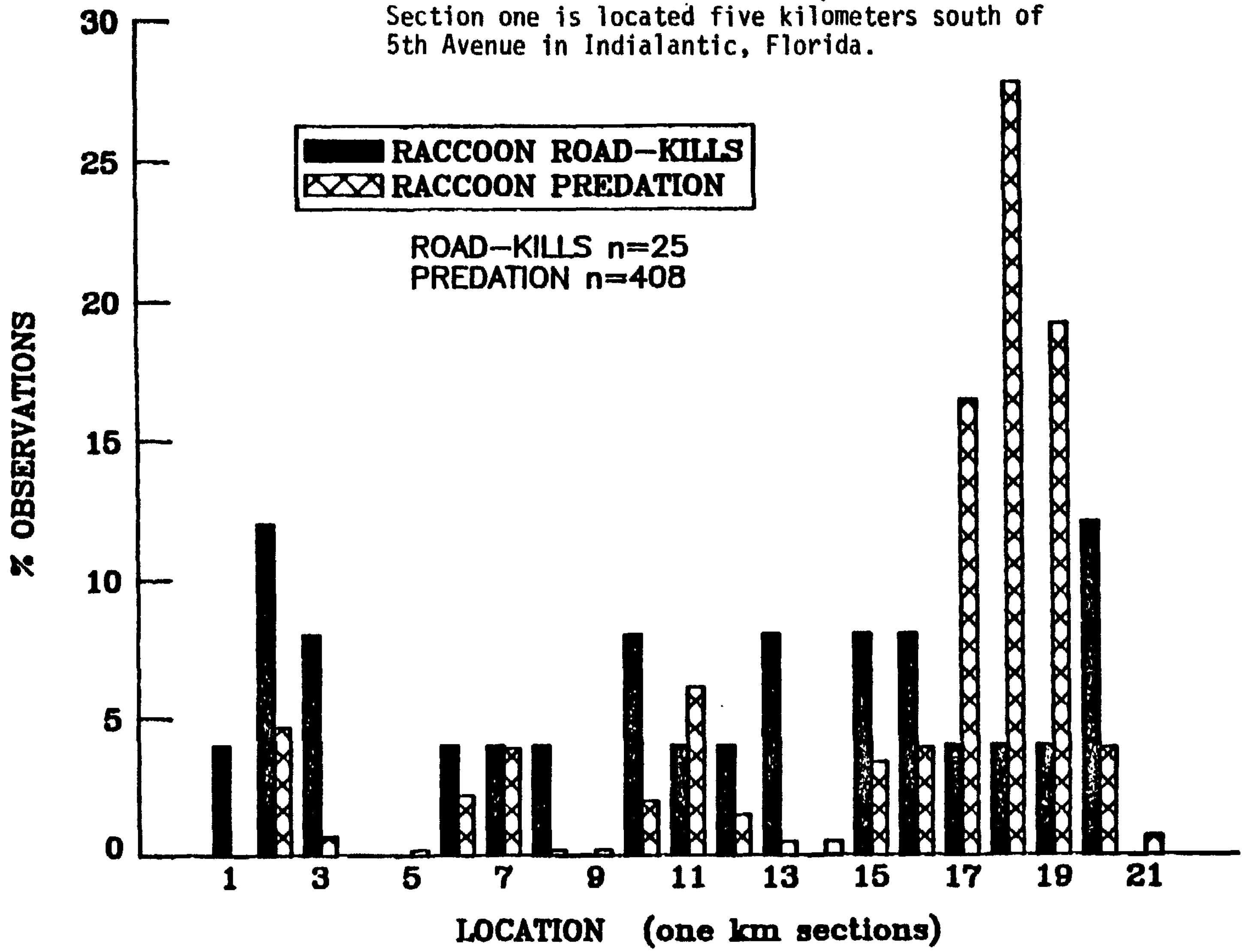


Figure 16. The spatial (horizontal) distributions of raccoon predation and raccoon road-kills on Highway A1A within the Melbourne Beach study area in 1985. Section one is located five kilometers south of 5th Avenue in Indialantic, Florida.



extensively on the beach but apparently caused no damage to marine turtle clutches. Emerging hatchlings were known, however, to have been trapped in the resultant holes.

Mortality Attributable to Humans

One clutch of loggerhead eggs was observed to have been taken by humans. Because poachers typically take fresh eggs from easily identified nests, all nests within the study area were observed during the time they were most susceptible to poaching. In addition to one nest taken, two other nests bore evidence of attempts to locate their eggs.

Vehicular traffic, banned on Brevard County beaches, appeared to continue sporadically with apparent impunity. On frequent occasions, evidence of large four-wheeled vehicles was observed on the beach. In several instances, deep ruts seriously delayed emerging hatchlings from reaching the surf. Nests being crushed by such traffic are documented by Mann (1977), though the extent of this mortality at Melbourne Beach was unknown.

Illegal dune reconstruction activities probably accounted for the destruction of a large number of marine turtle clutches; however, the extent of this mortality could not be quantitatively documented. Truckloads of sand were dumped over the dune onto the beach within four 100 m stretches of beach within the study area. It is reasonably certain that the nests beneath the dumped sand were suffocated . The use of heavy earthmoving equipment on the beach to aid in depositing the sand probably caused additional mortality.

Disorientation of hatchlings by artificial beachfront lighting was a major form of mortality attributable to humans. Hatchling disorientation is discussed in the following division.

Post-Emergence Hatchling Mortality

Ghost crabs were found to be the only major post-emergence predator of non-disoriented clutches. Because conditions revealing evidence of post-emergence hatchling mortality were not always ideal, evidence from sample nests was limited. An analysis was made from 48 observations of sample nests and randomly-chosen, natural hatchling emergences. An average of 0.5 hatchlings were taken by crabs from each hatchling emergence. Because many clutches had multiple hatchling emergences, the average number of hatchlings lost per clutch was slightly higher. These estimates are based on loggerhead hatchling emergences. Although green turtle hatchlings are slightly larger and may avoid some crab predation, green turtles also appear to display a greater frequency of multiple hatchling emergences. Regardless of an exact quantification, however, post-emergence hatchling mortality for both species was assuredly quite small.

Evidence of hatchling emergences disoriented by beachfront lighting was widespread. This phenomenon has been extensively documented by Raymond (1984a). Mortality suffered by disoriented clutches was judged by Mann (1977) to be very extensive, if not complete. This mortality is difficult to quantify because of the efficiency of scavengers in removing dead and dying hatchlings from the beach, the confusion of the resulting sign, and the uncertain fate of hatchlings that manage to enter the sea after a night of disorientation.

Hatchling disorientation rates of clutches were determined from observations of 1290 random, naturally occurring hatchling emergences. The spatial distribution of hatchling disorientation within the study area is represented by Figure 17. This distribution corresponds very closely to the areas of higher density development depicted by Figure 1, and consequently, areas with greater concentrations of beachfront lighting (observation).

Hatchling disorientations were judged as being major or minor. Table 14 lists the number of major and minor hatchling disorientations by ten-day periods. Of all hatchling disorientations, 64 percent were major and 36 percent were minor. Averaged for the season, 7.5 percent of all hatchling emergences within the study area were disoriented by beachfront lights.

This analysis of hatchling disorientation was based primarily on loggerhead hatchlings. With reasonable certainty, green turtle hatchling emergences could be differentiated from loggerhead ones. It is notable that no major hatchling disorientations were observed of green turtle clutches.

Recognizing the threat to marine turtle reproductive success, the Brevard County Commission adopted an ordinance restricting beachfront lighting. This ordinance was promulgated prior to the 1985 nesting season, but its effects were not immediately observed. Figure 18 displays rates of hatchling disorientation broken down by ten-day periods. Initially, over ten percent of all hatchling emergences were disoriented. Letters sent to beachfront residents by the Brevard County Planning Department and a door-to-door campaign to raise awareness of the lighting ordinance were successful in darkening many problem areas. Following these actions taken to darken the beach, rates of hatchling disorientation within the study area were immediately reduced.

Hazards to Nesting Females

No mortality to nesting marine turtles was observed within the

Figure 17. The spatial (horizontal) distribution of hatchling disorientation within the Melbourne Beach study area in 1985. Hatchling disorientation is expressed as a percentage of total hatchling emergences. Section one is located five kilometers south of 5th Avenue in Indialantic, Florida.

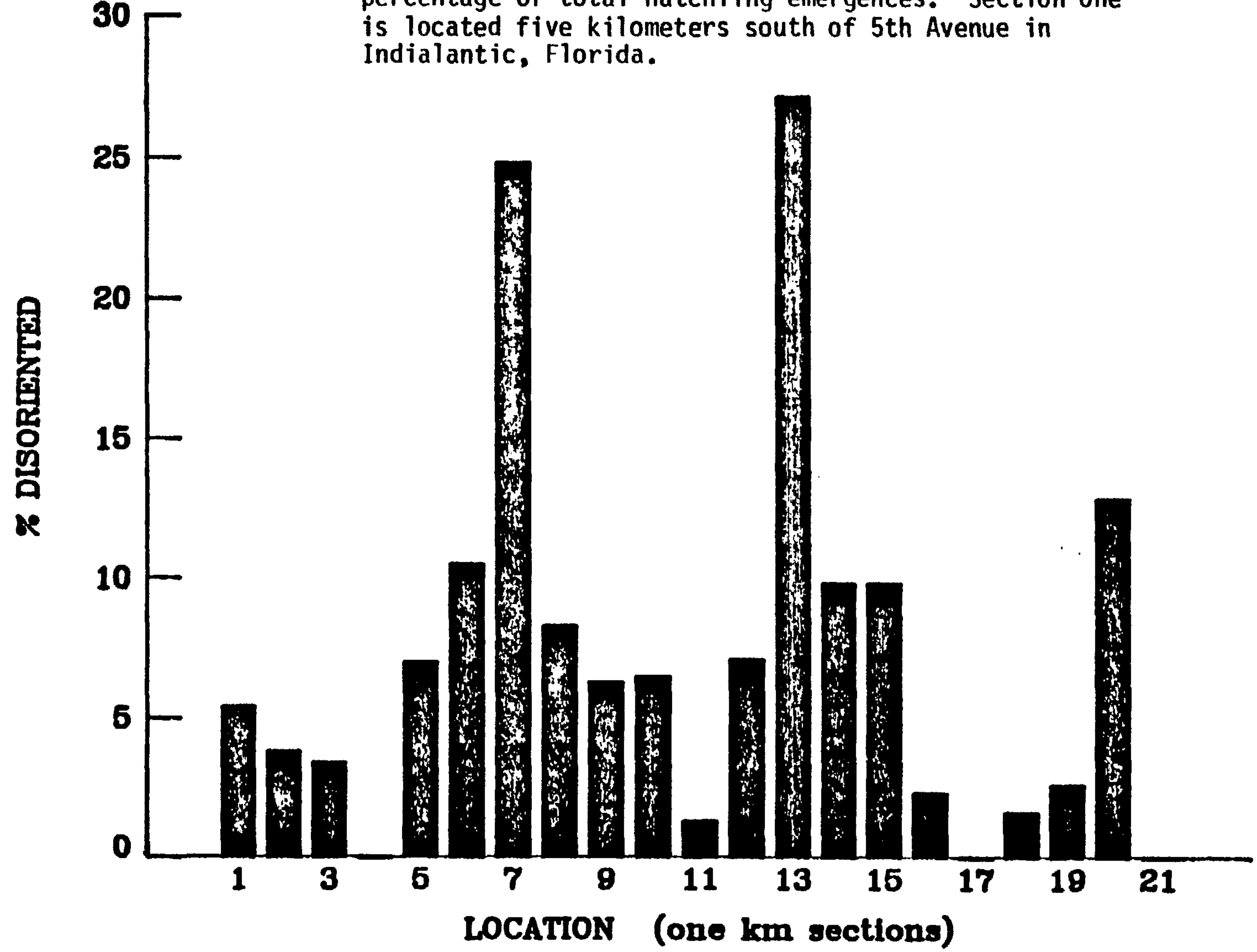
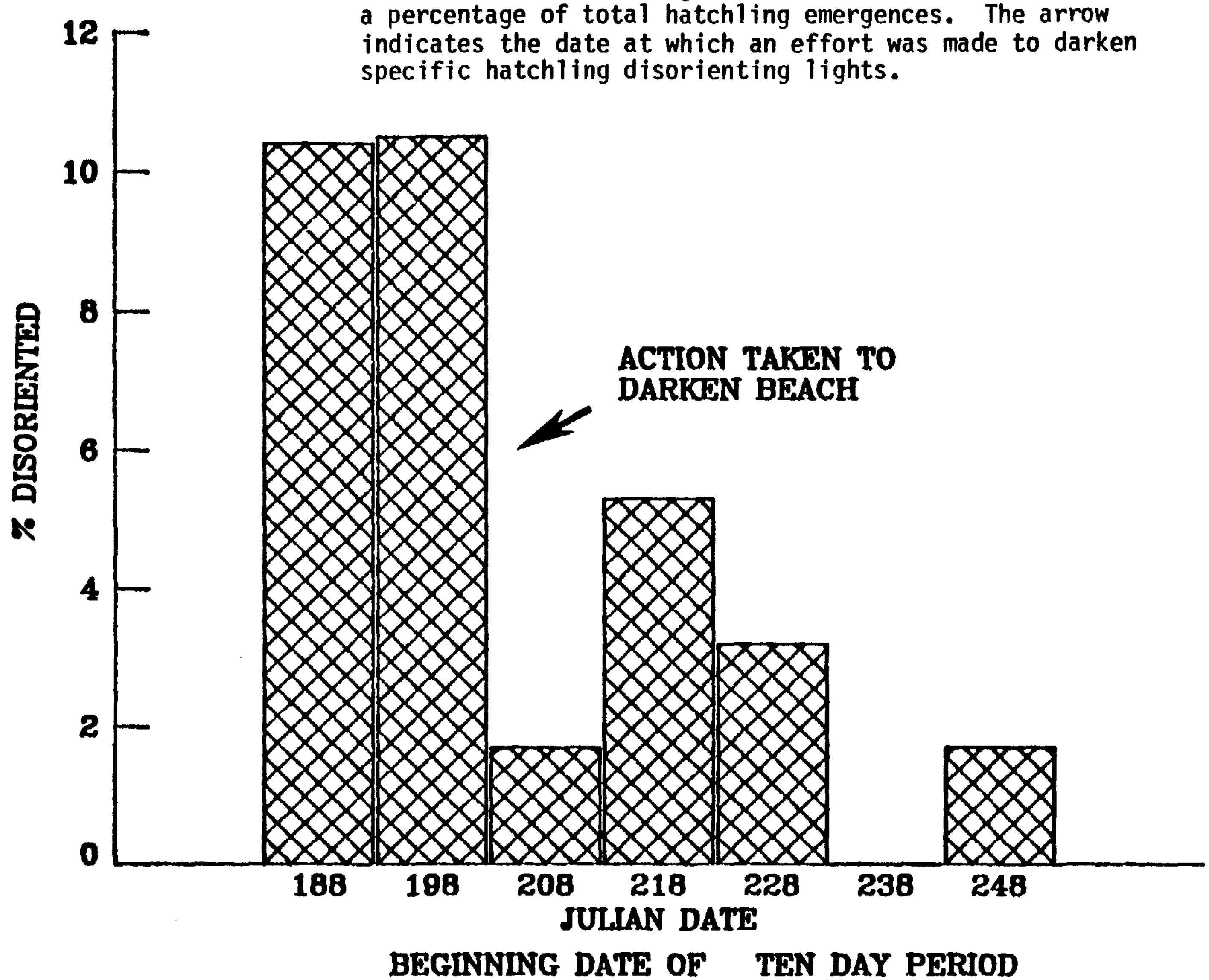


TABLE 14

Marine turtle hatchling emergences and disorientations observed on 21 km of beach in south Brevard County, Florida, 1985. Major disorientations are those which involve the majority of a clutch's constituents, while minor disorientations involve the minority. Observations are pooled into seven, ten-day periods.

Date (1985)	No. Observed Emergences	No. Observed Disorientations	
		Minor	Major
7-16 July	212	6	22
17-26 July	133	6	14
27 July-5 August	348	12	6
6-15 August	226	4	12
16-25 August	177	1	6
26 August-4 September	79	5	0
5-14 September	115	1	2
Total	1290	35	62

Figure 18. The temporal distribution (by ten-day increments) of hatchling disorientation within the Melbourne Beach study area in 1985. Hatchling disorientation is expressed as a percentage of total hatchling emergences. The arrow indicates the date at which an effort was made to darken specific hatchling disorienting lights.



study area. However, two subadult loggerheads (55-70 cm CLSL) that had apparently expired due to drowning and boat collisions were found washed ashore within the study area. Shrimp trawling, an activity associated with elevated mortality of turtles offshore waiting to nest (Hillestad et al., 1978), was observed only infrequently off the study area.

Observations of injuries to nesting turtles were few. One nesting loggerhead was found trapped beneath a wooden boardwalk during a daily nesting survey. The turtle was freed with no apparent deleterious effects. Evidence was observed of a nesting green turtle that had apparently undermined a cement block wall which partially collapsed on it, causing unknown damage to the turtle. Sign was also observed of a loggerhead that became trapped within a trench dug as part of a dune reconstruction project. The turtle apparently escaped after some extensive effort.

Human interference with nesting turtles was rather uncommon and, for the most part, unintentional. Evidence of nesting turtles being disoriented by bright, beachfront lights was observed, though this phenomenon was eliminated when the offending lights were dimmed. Non-nesting emergences prompted by difficulties in digging amidst sandbags and by the flashlights of well-intentioned "turtle watchers" were the only other human hinderances to marine turtle nesting attempts.

Analysis of Hatchling Production

The following quantification of hatchling production takes into account all mortality incurred during the terrestrial portion of the life histories of loggerheads and green turtles nesting at Melbourne Beach in 1985. Although this analysis provides an accurate assessment of hatchling production in 1985, the accuracy of future estimates will probably depend on variations in a few major causes of mortality. Two mortality factors which seem quite variable are mortality due to severe storms and mortality due to hatchling disorientation by artificial lighting. Mortality from both of these sources has been excluded from one of the following calculations, to represent a year in which no major storms strike and the problem of hatchling disorientation has been dealt with effectively. Some assumptions made are that loggerheads and green turtles suffer about the same level of post-emergence mortality and that green turtle hatchlings suffer negligible levels of mortality due to disorientation. Major hatchling disorientations are assumed to suffer 100 percent mortality while minor ones are ignored. These definitions accompany the analysis:

ES: mean emerging success of non-storm nests.

ESS: emergence success of non-storm nests.

CS: mean clutch size.

PEM: post-emergence mortality of hatchlings per non-disoriented clutch.

RHD: rate of hatchling disorientation among emerged clutches.

N: total nests deposited within the study area.

S: total nests not destroyed by storms.

TPH: total number of potential hatchlings = N x CS.

Production: the percentage of all potential hatchlings (yolked eggs) that successfully reach the surf.

The units of intermediate values in this analysis are numbers of eggs/hatchlings. A "model" year is one in which no severe storms strike and hatchling disorientation is negligible.

$$\text{Loggerhead Production in 1985} = \frac{(ESxSxCS)-[(PEMxESSxS)+(SxCSxESSxRHD)]}{TPH}$$

$$= \frac{615{,}244-(4936 + 39{,}329)}{1{,}189{,}888}$$

$$= \frac{570{,}979}{1{,}189{,}888}$$

$$= 48.0\%$$

$$\text{Loggerhead Production in a Model Year} = \frac{(ESxNxCS)-(PEMxESSxN)}{TPH}$$

$$= \frac{756{,}769 - 6071}{1{,}189{,}888}$$

$$= \frac{750{,}698}{1{,}189{,}888}$$

$$= 63.1\%$$

$$\text{Green Turtle Production in 1985} = \frac{(ESxSxCS) - (PEMxESSxS)}{TPH}$$

$$= \frac{20{,}760 - 137}{40{,}661}$$

$$= \frac{20{,}623}{40{,}661}$$

$$= 50.7\%$$

$$\text{Green Turtle Production in a Model Year} = \frac{(ESxNxCS) - (PEMxESSxN)}{TPH}$$

$$= \frac{23{,}908 - 157}{40{,}661}$$

$$= \frac{23{,}751}{40{,}661}$$

$$= 58.4\%$$

In 1985, an estimated 570,979 loggerhead hatchlings and 20,623 green turtle hatchlings left Melbourne Beach. Numbers of hatchlings produced in model years will vary depending on nesting densities.

Analysis of Data Incidental to Nightly Excursions

Of 301 loggerheads and 29 green turtles checked for previous tags, 17 percent and 14 percent, respectively, bore tags or evidence of tag loss. One green turtle and 39 loggerheads bore tags or tag remnants from which they could be fully or partially identified. Identifiable recoveries of nesting loggerheads are listed with their original locations and growth data in Appendix Table 7. Turtles originally tagged at the Kennedy Space Center Beach, Florida, were done so by L. M. Ehrhart. Tags with the prefixes B, C, E, and G were applied originally on Melbourne Beach by B. J. Turner. Tags with the prefixes D and T, and those beginning with the number 16, were applied on Melbourne Beach by P.W. Raymond and L. M. Ehrhart. Tags with the prefix SI were applied by Caretta Research, Inc., on Melbourne Beach. Tags with the prefixes FL and GA were applied, respectively, at the Canaveral National Seashore and Little Cumberland Island, Georgia, by J. I. Richardson.

Of 39 identifiable loggerhead recoveries, 33 were from Melbourne Beach, 4 were from the Kennedy Space Center beach, one was from the Canaveral National Seashore, and one was from Little Cumberland Island.

Based on dates of recovery, Melbourne Beach loggerheads appear to be nesting on two- and three-year cycles (Appendix Table 7). These data agree with evidence gathered by Richardson et al. (1978) on Georgia loggerheads and Bjorndal et al. (1983) on Florida loggerheads.

Growth rates of recovered loggerheads are compiled in Appendix Table 7. Except in one extreme case, negative growth data were included in calculating mean rates. Mean increase of loggerhead carapace length (straight line) was 0.15 cm/yr (SD = 0.24 cm/yr, n = 23) and mean carapace width (straight line) increase was 0.16 cm/yr (SD = 0.33 cm/yr, n = 21).

Intraseasonal recoveries were relatively uncommon. One loggerhead was observed nesting on Hutchinson Island, Florida, and a green turtle was observed nesting on Jupiter Island, Florida, after being tagged within the study area in 1985 (P. R. Witham, pers. comm.). Six loggerheads were observed during subsequent nesting attempts on Melbourne Beach. The average distance between nests of these turtles was 3.8 km, with a range of 18 to 77 days between nestings. One green turtle was observed nesting 29 days after she was initially observed and 0.05 km from her original nesting site.

DISCUSSION

Nesting Densities and Distributions

Nesting densities for loggerheads and green turtles in 1985 were the highest observed for the 21 km study area since surveys began four years ago (Table 1; Ehrhart and Raymond, ms.). Hobe Sound National Wildlife Refuge, Florida, also registered record densities of loggerhead and green turtle nests (Marcus, 1985). This information, together with reports from Hutchinson Island, Florida (Erik Martin, pers. comm.) and Sebastian Inlet State Recreation Area (Perry Smith, pers. comm.), confirms that 1985 was a very good nesting year for both species over a fairly broad geographic range in Florida.

While loggerhead nesting density at Melbourne Beach was indeed high, the relative increase in green turtle nesting in 1985 was much higher (Table 1; Ehrhart and Raymond, ms.). This phenomenal increase certainly indicates a substantial augmentation of nesting green turtles in 1985, but its relevance to overall population numbers is questionable. Green turtles are known to exhibit marked fluctuations in nesting densities from year to year at the Tortuguero, Costa Rica nesting beach (Meylan, 1982). These fluctuations are thought to indicate coinciding cycles in nesting activity among groups of nesting females. Because green turtles nest on two and three year cycles (Bjorndal et al., 1983; Carr and Ogren, 1960), this pattern would be expected to manifest itself in a relatively "poor" year for green turtle nesting in 1986. On the other hand, the extraordinary green turtle nesting in 1985 may indeed indicate the simultaneous arrival of a large cohort of recruits to the population of nesting females, or a concentrated immigration of nesting animals from other beaches. The latter possibility appears more realistic when one considers the dramatic effect that artificial beachfront illumination has on discouraging green turtle nesting. It may be that beachfront lighting is capable of drastically altering the distributions of green turtle nesting activity along Florida's coast. The superficial indication that the increase in numbers of nesting green turtles was actually a state-wide trend, however, bestows additional credence to Pritchards (1982) conclusion that Florida's endangered population of green turtles is slowly recovering.

Although seasonal variation in loggerhead nesting numbers is much more subtle than that of green turtles, some cyclic fluctuations have been observed. In fact, the "good" nesting year of 1985 corresponds to another "good" year in 1983 at Melbourne Beach (Ehrhart and Raymond, ms.) and Florida in general (Harris et al., 1984).

In the past 40 years or so, leatherbacks have been known to nest only sporadically along Florida's coast (Caldwell, 1959b, Harris et al., 1984). Leatherbacks nest almost exclusively on tropical beaches, so their minor participation in nesting at Melbourne Beach was not surprising.

Despite large daily variations in nesting activity, the nesting season for each species began and ended discretely (figures 3 and 4). Although loggerhead and green turtle nesting seasons broadly overlapped, a clear temporal partitioning was evident between the two species. Initial nesting of green turtles did not take place until one month after the first loggerhead nesting. As a result, the date at which the greatest number of loggerhead nests were incubating (22 July) was widely separated from that of green turtles (19 August). Because the green turtle nesting season was shorter, green turtles also had a greater percentage of nests incubating at this time than did loggerheads.

The devastating impacts of northeaster fall storms on late-season nest success may offer substantial selective pressure for marine turtles to nest during the more quiescent summer months. Nests of green turtles, however, are situated higher on the dune than are loggerhead nests (Table 2), which affords them some protection from storm-generated damage. Although the northeaster storms and surf erosion typical of the fall months generally selects against late season nesting, green turtles are apparently able to exploit nesting times later in the season than are loggerheads.

Another physical factor that may dictate the temporal realm of marine turtle nesting activity is temperature. Temperature is known to have profound effects on marine turtle clutches with respect to embryological development and survival (McGehee, 1979, Bustard, 1972), incubation period, and even the sex of the resulting hatchlings (Mrosovsky, 1980). Lower sand temperatures may be significant in restricting nesting of both species to the late spring and summer months.

Temporal partitioning between nesting loggerheads and green turtles has also been observed for the same species on the densely-nested island of Masirah, in the Indian Ocean (Ross and Barwani, 1982). A relatively high rate of density-dependent nest destruction is reported to occur at Masirah. In the past, Melbourne Beach may have also supported nesting of both species dense enough to conduce similar mortality. Temporal partitioning within physical limitations may have been very advantageous to each species in avoiding this mortality.

Spatial distributions of nesting activity also varied between species at Melbourne Beach. The horizontal (along the beach) distribution of loggerhead nesting in 1985 (Figure 5), closely resembles the distributions for three previous years (Ehrhart and Raymond, ms.). Such static distributions in nesting activity are speculated by Provancha and Ehrhart (ms.) to correlate with static discontinuities in beach profile. Hopkins and Murphy (1980) observed that drastic changes in beach profile on a South Carolina barrier island caused by a severe storm, substantially altered the horizontal distribution of nesting loggerheads. Within the Melbourne Beach study area, no objective investigation was made into relationships between nesting densities and natural beach attributes. There does certainly exist, however, some distinctly alluring attribute or set of attributes that consistently draws nesting turtles to Melbourne Beach. An analytical recognition of these attributes would be imperative, if any large scale beach reconstruction or renourishment projects are proposed for this important nesting beach.

The horizontal nesting distribution of green turtles (Figure 6) differed greatly from that of loggerheads. One attribute of the study area beach that apparently governed this distribution in green turtles, was the incidence of artificial beachfront lighting. Nesting green turtles clearly shunned areas of the beach that were brightly lighted to a much greater extent than loggerheads. Because nesting green turtles avoided lighted areas, their hatchlings were apparently not subjected to the disorientation and resulting mortality suffered by clutches that emerge in proximity to bright lights. Avoidance of lights was probably not a trait directly selected for in the evolution of green turtle nesting behavior. Such an increased discrimination in nest site choice, however, may have indeed promoted greater reproductive success, thereby fostering the genes of more discriminating animals. This notwithstanding, a definite spatial separation of nesting between species has resulted from the differential propensities governing loggerhead and green turtle nest site choice.

Although the horizontal distribution of loggerhead nesting activity was apparently affected minimally by beachfront lighting, loggerheads did seem to abort nesting attempts at a greater frequency in lighted areas (Figure 7). It is interesting to note that loggerheads aborted nesting emergences at a significantly higher frequency than green turtles. This may indicate when the "decision" to emerge and nest is made for each species. Green turtles may scrutinize nest-site choice to a greater extent pre-emergence, rather than while traversing the beach.

Loggerheads and green turtles also differed by the pattern in which their nests were distributed vertically along the beach grade (Table 2). Green turtles primarily chose nesting sites directly at the base of the primary dune, while loggerheads preferred the flat berm midway between the dune and the spring high-tide mark. Unlike loggerheads, green turtles undertake massive excavations while nesting, which are potentially destructive to any adjacent clutches. In addition, green turtle clutches are deposited deeper than loggerhead clutches and are better able to withstand similar assaults by nesting loggerheads. Although clutches deposited higher on the beach are better able to withstand storm-generated erosion, it may have been adaptively beneficial for loggerheads to adopt otherwise less-successful nesting sites seaward of the primary dune.

Mammalian predation may have also played a role in shaping vertical nesting distributions. A subjective appraisal of the vertical distribution of raccoon predation within the study area revealed what Routa (1967) also observed, that nests closer to the vegetated dune were depredated more frequently than nests farther out on the berm. The depth at which green turtle clutches were deposited appeared to discourage predation and may allow green turtles to more successfully exploit dune-base nesting sites.

Turtle Size, Clutch Size and Incubation Period

Incubation period length of marine turtle clutches is known to vary negatively with temperature (Bustard, 1972; Mrosovsky, 1980). Disparities in incubation period between Melbourne Beach and other nesting beaches were probably due primarily to differences in sand temperatures, though other environmental vicissitudes may also play a role. The average incubation period of loggerhead clutches at Melbourne Beach (53 days), was expected to be somewhat shorter than that reported for South Carolina beaches (55 days, Caldwell, 1959a). The differences noted between Melbourne Beach green turtle nests (54 days) and average incubation periods from Costa Rica (62 days, Fowler, 1979) and Surinam (58 days, Pritchard, 1969) were quite surprising. Both Costa Rica and Surinam lie in the tropics at latitudes 16 and 21 degrees south of Melbourne Beach. During the summer solstice (21 June), however, Melbourne Beach lies closer to the region of maximum solar intensity (Tropic of Cancer) than Costa Rica or Surinam. A predominance of cloudy or rainy days during the nesting season may also limit solar exposure on these tropical beaches. Shading of nesting sites may dramatically lengthen incubation times. Some of the green turtle nests in Fowler's study were deposited in shaded areas and exhibited incubation periods as long as 81 days. No such shaded sites were available for nesting turtles at Melbourne Beach in 1985.

Nesting female size (CLSL) and clutch size of loggerheads nesting on Melbourne Beach were very similar to those measures reported for other nesting areas. Mean clutch size of Melbourne Beach loggerheads (116 eggs) did not differ greatly from means reported for Cape Canaveral, Florida (110 eggs; Ehrhart, 1979), Little Cumberland Island, Georgia (120 eggs; Richardson and Richardson, 1982), and Natal, South Africa (117 eggs; Hughes, 1971). Mean CLSL of loggerheads nesting at Melbourne beach (92.2 cm) did not differ significantly from measurements made of loggerheads from Cape Canaveral (92.2 cm; Ehrhart, 1979) and Natal (93 cm; Hughes, 1970).

There were significant disparities, however, between Melbourne Beach green turtles and other populations, with respect to adult female size and clutch size. Mean clutch size of Melbourne Beach green turtles (145 eggs) differed significantly (students t-test, $P < 0.05$) from those means reported from Tortuguero, Costa Rica (110 eggs) and Ascension Island (116 eggs) by Carr and Hirth (1962); Sarawak (105 eggs; Hendrikson, 1958); Heron Island, Australia (110 eggs; Bustard, 1972); and French Frigate Shoals, Hawaii (104 eggs; Balazs, 1980). Mean clutch size of green turtles at Melbourne Beach was very similar, however, to that reported by Pritchard (1969) for Surinam green turtles (142 eggs). Oddly, mean clutch size differed significantly between Cape Canaveral (130 eggs; Ehrhart, 1979) and Melbourne Beach green turtles. Both of these means for Florida green turtles, though, were significantly larger than those of the aforementioned populations, except for Surinam green turtles.

Clutch sizes of Florida green turtles have been reported historically by Monroe (1898) to range from 130 to 180 eggs and by Audubon (1926) to average about 140 eggs. Although these historical accounts should be accepted cautiously, they do give some indications that Florida green turtles have consistently exhibited large clutches. Expressions of fecundity, like clutch size, may be controlled by both genetic and environmental factors. This evidence, therefore, leads one to believe that Florida's population of green turtles is at least environmentally isolated, if not genetically distinct, from other Atlantic populations.

The selective advantage of large clutches is the obvious increase in potential progeny. Environmental and physiological constraints, however, ultimately dictate the upper limits of clutch size. Mortimer (1981) suggested that sand grain size on the nesting beach may limit clutch size by governing oxygen diffusion within the incubating clutch. Mortimer speculated that larger sand grain size may facilitate a greater rate of oxygen diffusion. Larger clutches require higher rates of oxygen diffusion, due to the increased metabolic oxygen consumption of more eggs and a lower surface area to volume ratio (Ackerman, 1977). Sands of Melbourne Beach are coarse grained with a significant biogenic component consisting primarily of crushed shell. Considering the success observed for green turtle nests within the study area, large green turtle clutches fare quite well under Melbourne Beach's edaphic conditions.

Mean size (CLSL) of green turtles nesting at Melbourne Beach (101.5 cm) was found to be significantly larger (student's t-test, $P < 0.05$) than that reported for French Frigate Shoals (92.2 cm; Balazs, 1980), but significantly smaller than means reported from Bigi Santi, Surinam (111.8 cm; Pritchard, 1969) and Ascension Island (108.1 cm; Carr and Hirth, 1962). Mean CLSL was found not to differ from means calculated for green turtles from Tortuguero (100.0 cm; Carr and Goodman, 1970) and Cape Canaveral (99.5; Ehrhart, 1979).

Size differences between Florida green turtles and other populations probably do not involve disparate age structures between the populations. Such an argument is presented by Carr and Goodman (1970) in which they speculate that mean size differences between populations reflect, for the most part, differential sizes at which the animals reach sexual maturity. Whether such disparities are governed by genetic or environmental factors has yet to be determined.

A significant positive correlation was found between body size of nesting loggerheads and green turtles, and their respective clutch sizes (Figures 8 and 9, Tables 3 and 4). Hirth (1971) also reported that larger green turtles deposited larger clutches. This phenomenon has been reported, likewise, for other turtles such as _Pseudemys scripta_ (Gibbons, 1970), _Chelydra serpentina_ (Yntema, 1970) and _Sternotherus odoratus_ (Tinkle, 1961). This reinforces the hypothesis that somatic constraints are influential limitors of clutch size in turtles.

Loggerhead clutch sizes were found to be negatively correlated with their respective dates of deposition (Table 3). Frazer and Richardson (1985) found that for loggerheads nesting on Little Cumberland Island, the number of eggs deposited in the final clutch of the season for the average nesting female was typically smaller, though not significantly so. Smaller final clutches may manifest a trend toward smaller clutches later in the season and could explain the negative correlation between season date and clutch size. To fully elucidate this phenomenon among Melbourne Beach turtles, however, an analysis should concentrate on monitoring successive clutches of individual turtles and not assessing temporal trends of the population.

A significant negative correlation was found between the size of loggerhead nesting females and the date on which they nested (Table 3). This correlation accompanies the general observation that larger turtles were more common earlier in the season. Larger individuals may make the extensive migration from the foraging grounds (Bahamas, Hispanola, Cuba; Meylan et al., 1983) to the nesting beach in a shorter time than smaller individuals. Such a size advantage in nesting migrations was proposed by Carr and Goodman (1970) with respect to the arduous migrations of Ascension Island green turtles. Given the relationship between body size and clutch size, the arrival of smaller loggerheads later in the season may contribute to the observed negative correlation between clutch size and date.

Information on Movements of Nesting Females

Nesting site philopatry and site fidelity are terms used by Carr et al. (1978) in describing tendencies of marine turtles to nest faithfully on a single stretch of beach or closely situated beaches each year they nest. These tendencies were investigated for Melbourne Beach loggerheads, using information from 39 interseasonal recoveries of previously tagged animals. These recoveries confirm earlier results of Bjorndal et al. (1983), which indicated that Melbourne Beach loggerheads do not display the type of religious site fidelity observed in green turtles (Carr et al., 1978). Interseasonal recoveries of loggerheads on Melbourne Beach (Appendix Table 7) were of turtles tagged as far away as Georgia. Ten percent of these recoveries were from another major site where nesting females are tagged, about 70 km north of the study area (Cape Canaveral). Most of the remaining recoveries were from turtles tagged as they nested on Melbourne Beach during previous nesting seasons. Two of these recoveries were from Loggerheads tagged on Melbourne Beach 12 and 13 years prior to this study. These are among the longest recovery intervals reported for nesting loggerheads.

Intraseasonal recoveries of nesting loggerheads also showed loggerheads to be less site tenacious than green turtles. The mean distance between recoveries of nesting loggerheads within the 1985 season was about 4 km. Green turtles nesting at Tortuguero, Costa Rica are known to regularly make successive nesting emergences within 200 m of previous sites (Carr et al., 1978).

Of two green turtles that were observed on successive nestings at Melbourne Beach, one nested within 50 m of its preceding nest, while the other was observed nesting roughly 100 km to the south at Jupiter Island (P.R. Witham, pers. comm.). The latter turtle may have been severely frightened during a subsequent emergence, enough so to prompt an expansive search for a more suitable nesting site. Behavior of this sort is generally not seen in green turtles.

Reproductive Success and Productivity

Measures and Comparisons

Most of the comparative analyses of reproductive success thus far have excluded data from nests that were destroyed in the severe

September storm. Because destructive storms like this are relatively uncommon, an assessment excluding damage from storm provides a more generalized baseline for comparisons. Throughout this section, unless otherwise mentioned, measures of success are derived from non-storm nests.

Differences between hatching and emerging success were very small for both species (Appendix tables 5 and 6). This indicates that the vast majority of hatchlings that developed to term and pipped the egg, emerged from the nest successfully. Likewise, mortality of hatchlings en route from nest to surf was also found to be very small. The actual rate of mortality for clutches emerging under conditions similar to those at Melbourne Beach is probably also quite low.

Although actual hatchling production differed greatly between loggerheads and green turtles, the average success of individual nests was statistically similar. The actual hatchling production on Melbourne Beach in 1985, including mortality from the September storm, was estimated to be ca. 571,000 loggerhead and 21,000 green turtle hatchlings. This extraordinarily high production may be much greater during a season in which no major storms strike. Such a model year may see ca. 751,000 loggerhead and 24,000 green turtle hatchlings leave the Melbourne Beach study area. In all probability, this area produces more Florida green turtle and loggerhead hatchlings than any comparable extent of Western Atlantic nesting beach.

Ideally, comparisons of reproductive success between nesting beaches should be made with values averaged over a number of nesting seasons. Unfortunately, very few of these assessments exist, let alone any that include data for more than a single season. Reproductive success on Melbourne Beach, or any other beach, undoubtedly varies among years, depending primarily on major but infrequently random events such as storms. Other major factors that influence mortality, including mammalian predation, are probably expressed with relative consistency as long as the environmental conditions of the beach remain somewhat constant. Therefore, single-season assessments of success are probably quite indicative of past and future success, as long as they do not reflect catastrophic events. For purposes of this argument, their comparative use is analytically worthwhile.

Various estimates and assessments of reproductive success on other beaches exist in the literature. Estimates of emerging success based on predation rates given in the literature were calculated, assuming that non-depredated clutches were undisturbed and exhibited emergence successes similar to undisturbed Melbourne Beach nests. Error in these estimates is probably positive.

Actual emerging success of loggerhead and green turtle nests at Melbourne Beach, including nests destroyed by storms, was 52 and 51 percent in 1985. The same assessment of loggerhead and green turtle emerging success, excluding storm-destroyed nests, was 64 and 59 percent. Based on the reported percentage of clutches that emerged and the average success of emerged clutches, emerging success for loggerhead nests at Cape Island, South Carolina in 1939 was about 32 percent (Caldwell, 1959a). Hopkins et al. (1978) estimated this value at only 6 percent for the same beach in 1977, because of severe predation by raccoons. Blanck and Sawyer (1979) estimated emerging success of loggerhead nests at Ossabaw Island, South Carolina to be 0 percent, again primarily due to raccoon predation. Raccoons have also been recognized as major success-limiting factors on Florida beaches. Based on predation rates, emerging success of loggerhead nests was estimated to be 0 to 15 percent on Cape Canaveral beaches (Ehrhart, 1976; Schroeder, 1981), about 30 to 40 percent at Hutchinson Island (Routa, 1967; Gallagher et al., 1972; Worth and Smith, 1976) and 5 to 27 percent on Cape Sable beaches (Davis and Whiting, 1977). Dogs (Canis) and coatis (Nasua) were substantial predators of green turtle eggs in Fowler's (1979) study in Costa Rica, where emerging success averaged 35 percent. Ross and Barwani (1982) estimate emerging success of loggerhead nests to average about 24 percent on the island of Masirah, where the surf is reported to regularly take 40 percent of all deposited clutches.

Hobe Sound National Wildlife Refuge, Florida, apparently had rates of emerging success in 1985, comparable to those observed for Melbourne Beach. Averaged estimates of loggerhead and green turtle emerging success were 45 and 47 percent, including nests destroyed in the same September storm that affected Melbourne Beach (Marcus, 1985). Part of the high relative success of marine turtle nests on the Hobe Sound beach can be attributed to raccoon control measures that were instated to curtail predation of nests, which was historically quite extensive.

The rate of reproductive success of marine turtle nests at Melbourne Beach appears to be relatively high. There are also indications in the literature that past years may have been just as successful. Subjective reports of raccoon predation at Melbourne Beach (Bjorndal et al., 1983; Raymond, 1984b) indicate that at least in the past ten years, raccoon predation has been very low. Current levels of raccoon predation may, in fact, be elevated over historical ones, because of increased raccoon densities. Raccoons are well-known human symbionts and may exist in greater numbers since the development of the barrier island by humans. The original barrier island was a narrow strip of xeric habitat with little fresh water and was probably capable of supporting only small densities of raccoons.

The only measured physical factor found to significantly affect emerging success of sample nests was the vertical nest site choice of the nesting loggerheads (tables 6a and 6b). Numbers of green turtle nests deposited in the more seaward zones were too few to permit a similar analysis for green turtles. Loggerhead nests in the center of the berm fared best, while nests deposited lower on the beach were more frequently destroyed by the surf, and nests deposited closer to the dune were more frequently destroyed by predators and plant roots. It does appear, therefore, that the vertical distribution of nest site choice of nesting loggerheads correlates with reproductive success over the same dimension.

Factors Affecting Reproductive Success

The following discussion addresses loggerhead and green turtle, clutch and egg fates illustrated in figures 10 through 13 and tables 8 through 11.

Mortality Influenced by Numbers of Nesting Females-

The destruction of incubating clutches by nesting females observed at Melbourne Beach is probably closely tied to the number of nesting females that use the beach. This type of mortality is thought to be quite severe on the densely utilized loggerhead nesting beaches of Masirah (Ross and Barwani, 1982) and Heron Island, Australia (Bustard, 1972). Although the level of this nest destruction is apparently quite low at Melbourne Beach, nesting densities may have once been high enough for such mortality to play a role in population regulation.

A form of mortality which may be indirectly linked to nesting densities was the edaphic concentration of microbial pathogens. Microbes were probably the primary cause of failure of eggs that displayed addled contents or developmentally arrested embryos. Many of these egg contents were stained pink from bacterial infections or had substantial growth of fungi within the shell. Solomon and Baird (1979) report that even undisturbed healthy eggs of marine turtles are prone to invasion by fungal hyphae. Elevated levels of bacteria and fungi in the sand of Melbourne Beach from heavy concentrations of rotting eggs from present and past seasons, may make this a density-dependent phenomenon.

Damage related to sand accretion and surf -

Mortality of eggs due to the accretion of sand over loggerhead nests was an unexpected phenomenon. The actual cause of failure of the affected clutches was assumed to be suffocation. The eggs of clutches destroyed in this manner were otherwise undisturbed, entire, and often contained embryos whose development had been simultaneously arrested. Ackerman (1977) has demonstrated that the depth and type of sand surrounding marine turtle clutches greatly influences embryonic growth and mortality. Sand that was accreted over nests due to storms was apparently moved by wave action, not wind. In addition to changing the quantity of sand over the clutch, this wave-deposited accretion may also have changed the quality and arrangement of sand as well. Whether these clutches were actually destroyed due to accretion of sand or were affected by wave wash, is unknown. Green turtle clutches seem to have avoided mortality from sand accretion, which for the most part, affected a zone outside the one where green turtles most frequently nested.

Erosion and wave wash due to heavy surf conditions are known to exact heavy mortality on many nesting beaches (Mortimer, 1981; Ross and Barwani, 1982; Small, 1982). Barring major storms, however, mortality from erosion and inundation at Melbourne Beach was very low. Although very few nests (especially those of green turtles) were deposited in the zone of heaviest surf erosion, a number of nests received moderate, periodic wave wash. McGehee (1979) suggested that this moderate wave wash is relatively innocuous. The relatively high success of moderately wave-washed nests at Melbourne Beach tends to support this.

The primary cause of failure of clutches affected by surf conditions was not drowning or dessication, but the partial exposure or total loss of a clutch due to erosion.

Damage due to storms -

The single, five-day northeaster storm that battered the study area beach in mid-September was the principal cause of marine turtle clutch mortality in 1985. About 19 and 13 percent of all loggerhead and green turtle nesting for the season was destroyed in this storm. Damage from severe storms has the potential to be much higher, though there is a definite limit to the destruction a single storm can cause. An analysis, based on the temporal distribution of loggerhead nesting at Melbourne Beach, reveals that the greatest mortality caused by a single storm would be about 63 percent of all clutches. This would be the case, providing the storm strikes about 22 July, when the greatest number of loggerhead clutches are still incubating, and destroys all incubating clutches. Such severe damage could only be administered by a major hurricane. Besides major hurricanes, the most destructive type of storm to marine turtle clutches appears to be the lingering northeaster, such as the one that struck the study area in 1985. This storm was observed to generate much more destructive erosion than the more violent but fleeting tropical storms. The typical appearance of northeaster storms in the autumn months may have been very influential in determining the period in which marine turtle nesting is most successful.

Raccoon predation -

The rate of raccoon predation on marine turtle clutches at Melbourne Beach is quite low compared to other beaches in the southeast United States, where the raccoon is the primary cause of clutch failure. The proximity of Highway A1A to the study area beach is probably a significant factor in the reduction of raccoon population density there. The highway mortality for four months within the twenty-one kilometers surveyed was 25 raccoons, which was probably a substantial toll on the population.

The low rate of raccoon predation at Melbourne Beach may not be entirely due to low raccoon population densities, though. Melbourne Beach raccoons display a markedly naive approach to marine turtle nest predation. As an example, the raccoons at Melbourne Beach were almost never known to depredate fresh nests. This is in striking contrast to the raccoons of Cape Canaveral that excavate and destroy nearly every clutch on the beach within hours of deposition (L. M. Ehrhart, pers. comm.). It is likely that Melbourne Beach raccoons do not visually recognize the disturbances left in the sand by nesting turtles as potential sources of sustenance. Melbourne Beach raccoons appear to locate clutches primarily by olfaction, depredating only those clutches that generate the wafting odor of pipping eggs during late incubation or those clutches that have had eggs broken by invading ghost crabs. The latter case explains the preponderance of clutches that were depredated during early and middle incubation, when all visual and olfactory evidence would have normally been absent. Given the high percentage of nests entered by ghost crabs, raccoons would have had ample opportunities to "follow their noses" down crab burrows to otherwise inconspicuous clutches.

In addition to the relative ineptitude of raccoons that did destroy nests, the majority of raccoons at Melbourne Beach apparently did not depredate nests at all. A relative measure of raccoon population density (road-kills) indicated that raccoons inhabited roughly the entire study area. Predation of nests by raccoons, however, was largely concentrated in only three of the twenty-one kilometers (Figure 16). Most of the nest depredation at Melbourne Beach can probably be attributed to a small number of individual raccoons that have learned to exploit turtle nests as a food source.

Raccoon predation of turtle nests was small enough, in relation to sample size, to invalidate any statistical comparison between loggerheads and green turtles. Subjectively, however, green turtle nests appeared to be depredated less often than loggerhead nests. The difficulty in excavating the deeper clutches of green turtles may have inhibited some raccoon predation.

Ghost crab predation -

Although ghost crabs invaded a large percentage (about one third) of all loggerhead and green turtle clutches, the total number of eggs destroyed by ghost crabs was proportionately small (2 - 5%). Ghost crabs were also found to be minor predators of eggs on South Carolina beaches (Hopkins et al., 1978; Caldwell, 1959a) and at Tortuguero, Costa Rica (Fowler, 1979). As an exception, Hill and Green (1971) found that ghost crabs destroyed a fairly large percentage of green turtle eggs (12%) on Bigi Santi Beach, Surinam.

Ghost crabs at Melbourne Beach were found to construct their burrows with different frequencies in old nests, fresh nests and undisturbed beach (Table 13). Burrow site choice for ghost crabs is probably linked closely to substrate friability. Ghost crabs were found to burrow with greater frequency in moist, less friable sand, such as the tilled substrate provided by fresh nests. Ghost crabs also appeared to prefer undisturbed beach over substrates made drier and more friable by a weathered disturbance such as an old nest. This burrowing preference held true for disturbances other than marine turtle nests. Based on subjective observations, Warner (1977) drew similar conclusions with respect to ghost crab burrowing behavior.

It appears, therefore, that the discovery of marine turtle clutches by ghost crabs is not a systematic search based on olfaction, but may instead be a fortuitous windfall, owing to the selection of marine turtle nests as preferential burrowing media. The stereotypic behavior of a nesting marine turtle dispersing sand over her clutch could therefore be construed as being disadvantageous, if predation by ghost crabs was a major selective agent. What this may tell us, however, is that the evolutionary influence of ghost crab predation on the behavior of nesting marine turtles was quite small. Nest obliteration behavior of marine turtles is probably in response to the incomparably adverse impact of mammalian predation.

Ghost crabs were found to be the primary predator of post-emergent loggerhead hatchlings, though their contribution to overall mortality was quite small. Predation of hatchlings by ghost crabs en route from nest to surf is probably limited by the number of crabs in the vicinity of the hatchling emergence which are robust enough to subdue a frenzied hatchling. Whether green turtle hatchlings avoid predation by ghost crabs to some extent, by virtue of their slightly larger size, is unclear.

Damage from plant roots -

The destruction of loggerhead and green turtle clutches by beach morning-glory and sea oat roots was a curious case of role reversal. "Depredation" of marine turtle clutches by sea oats has also been reported by Caldwell (1959a) and Raymond (1984b). Given the extent of root growth and the pattern of mortality within the clutches involved, it is reasonably certain that the penetration of eggs by the plant roots was the primary cause of mortality and was not an incidental post-mortem event.

The dune plants, apparently by design or by chance, exploit the marine turtle clutches as moisture and nutrient sources. While this relationship is assuredly beneficial to the plants and detrimental to the turtle's clutch, it is not obvious whether the plants possess any relevant adaptations besides the deep, rapidly growing root system that is a standard attribute of dune plants.

Human induced mortality -

In general, beachfront residents and visitors to Melbourne Beach were very protective of the marine turtles that nested on their beach. Mortality to eggs and hatchlings caused by humans was, for the most part, incidental to non-malevolent actions. Despite these good intentions, however, there were several moderate to severe impacts on marine turtle reproductive success that resulted directly from turtle-human cohabitation of the beach.

Poaching of marine turtle clutches was very infrequent, with only one case in over ten thousand nests recorded. The vigilance of beachfront residents at Melbourne Beach was probably enough to discourage most would-be poachers.

A relatively severe impact on clutch survivorship was the frequent deposition of sand and debris on the beach by property owners in attempts to stabilize and rebuild their dune. Such construction practices are prohibited without special permits from the Florida Department of Natural Resources, permits which are not granted during the marine turtle nesting season. In all cases the sand dumping activities were completed within a single day, so that stopping them was, in effect, too late to prevent the destruction of marine turtle clutches. Judging by the quantities of sand and debris deposited on the beach and the densities of marine turtle nests involved, approximately one hundred clutches may have been destroyed by these actions. It is clear that a more rigorous enforcement of existing codes is needed on this valuable stretch of marine turtle nesting beach.

By far, the most serious human-induced threat to marine turtle reproductive success currently manifesting itself on Melbourne Beach is the disorientation of hatchlings by artificial beachfront lighting. Hatchling disorientation from lights has also been judged a serious threat on the densely-developed nesting beaches of southeastern Florida (McFarlane, 1963; Mann, 1977). Mortality among disoriented clutches was apparently very high. In addition to disorienting the nocturnal emergences of hatchlings on the beach, artificial lights were also observed to draw hatchlings from the surf that had already entered the ocean. This phenomenon has been similarly reported by Carr and Ogren (1960). Such a strong affinity to lights must also cause hatchlings to linger in the surf near brightly lighted areas. This would certainly increase the rate of mortality from predatory surf zone fishes and draw from already diminished energy resources needed by hatchlings for their upcoming pelagic journey.

Artificial beachfront lighting generates many obviously detrimental ramifications with respect to marine turtle reproductive success. Some other impacts of a lighted beach may be just as, if not more serious, but have yet to be identified. Considering the serious consequences, beachfront lighting is certainly a conservation problem to be remedied. An important step taken toward mitigating this problem was the passage of an ordinance prohibiting beachfront lights within the unincorporated areas of Brevard County. This ordinance, which was passed prior to the nesting season in 1985, was however, initially ineffective in darkening the beach. Individual contacts with offending property owners were needed to encourage the turning off of lights. Following this somewhat extensive effort, the beach became noticeably darker. The dramatic decrease in the rate of disorientation on the darkened beach (Figure 18) demonstrates that the problem of hatchling disorientation is certainly a manageable one.

One human-induced threat to marine turtle reproductive success at Melbourne Beach, of potentially great importance, is presently an incipient one. The dune at Melbourne Beach is almost entirely in private ownership and is currently being developed at an explosive rate. One need only trace the history of privately owned beachfront property in Florida to realize that the end result is one that is generally unacceptable for the successful nesting of marine turtles. Although very few beach-damaging seawalls and revetments presently exist at Melbourne Beach, the forces of nature are irreversibly in progress that will ultimately prompt their installation by worried condominium and hotel owners, as properties continue to erode. An assessment of measures that could be taken to protect Melbourne Beach from this process is greatly encouraged, but is beyond the scope of this report.

Offshore predation -

Surf zone and offshore predators of hatchlings obviously did not affect the values reported for ocean-bound success. Their substantial effect on overall hatchling recruitment, however, requires that some analysis of the limited data be made. Interviews with resident surf fisherman were made to acquire any evidence indicating predation of hatchlings by fishes. The stomachs of 27 bluefish (*Pomatomus saltatrix*), three red drum (*Sciaenops ocellata*) and one small blacktip shark (*Carcharhinus limbatus*) were examined directly or vicariously without discovering any hatchlings. Many of the fishermen interviewed were convinced that red drum were the primary surf zone predator of hatchlings, based on past evidence of hatchlings in their stomachs. Some fishermen in fact, were certain that the fish congregated around areas of the beach that produced large numbers of hatchlings. The catch of red drum was very poor off and around Melbourne Beach in 1985. Although the effect of surf zone fish predation on hatchling recruitment is not quantified, the absence of such a major predator may have had significant consequences with respect to the number of hatchlings entering the pelagic environment.

The Importance of Melbourne Beach as a Marine Turtle Rookery

This study has made it clear that, because of extraordinary levels of nesting density and reproductive success, Melbourne Beach produces an outstanding, perhaps unequaled, number of Florida green turtle and loggerhead hatchlings. It is clear that this beach is a vital source of recruitment for these endangered populations. Our current paucity of knowledge regarding population dynamics of marine turtles, however, restricts our assessment of "adequate" and "inadequate" levels of hatchling recruitment. In striving to conserve these species, therefore, a prudent course of action would be to mitigate factors that cause excessive mortality to eggs and hatchlings on those beaches that have elevated potentials as hatchling producers (high density nesting beaches).

The value of Melbourne Beach as a marine turtle rookery lies in the fact that even without arduous and expensive management practices, it is a very prolific producer of marine turtle hatchlings. This value certainly entitles Melbourne Beach to the designation of "Critical Habitat" proposed by Dodd in 1978. Regardless of the nomenclature, Melbourne Beach is in need of some protective, regulatory status; a status that would incorporate measures to assure that Melbourne Beach retains the attributes that justify the extensive and successful concentration of marine turtle reproductive effort there.

MANAGEMENT RECOMMENDATIONS

The following summaries of recommendations are deemed very important to the conservation of Melbourne Beach's threatened and endangered marine turtles.

1. Special Status - The Melbourne Beach area (Figure 1), or parts thereof, should be given special status as a marine turtle sanctuary. This auspice should incorporate protective guidelines that would curtail detrimental and potentially detrimental activities affecting this demonstrably important nesting beach. Designation as Critical Habitat under the Endangered Species Act would be an appropriate starting point.
2. Monitoring - Monitoring on the nesting beach is very important if deleterious impacts are to be recognized and acted on promptly. Monitoring human activities such as vehicular traffic, dune restoration, and beachfront lighting, coupled with subsequent mitigation by the enforcement of already-existing codes, is the most cost-effective and sensible method of bolstering reproductive success at Melbourne Beach. Other success-limiting factors, such as raccoon predation, should also be monitored, so that informed decisions concerning management can be made.
3. Management - Although reproductive success at Melbourne Beach is relatively high, substantial benefits are inherent in mitigating a few readily accessible sources of mortality. No single source of

mortality affected a large percentage of marine turtle clutches on Melbourne Beach. Because of high nesting densities, however, even small percentages of the nesting effort translate into large numbers of clutches. Removing a small number of raccoons from the limited area affected by predation would save hundreds of loggerhead clutches. Likewise, encouraging more residents to comply with the ordinance restricting beachfront lighting would save thousands of loggerhead hatchlings.

4. Regulation of Nearshore Activities - Because thousands of adult turtles congregate in the waters off Melbourne beach during the breeding season (April-August), any deleterious human activity or influence in this region could have serious consequences. The required use of the National Marine Fisheries Service's "Turtle Excluder Device" on shrimp trawlers operating off Melbourne Beach is one example of an action that would mitigate mortality of adult turtles. Further research may be needed to find ways to mitigate other human impacts such as dredging.

5. Research - Melbourne Beach's value as a productive marine turtle rookery also makes it an important area for scientific research. Marine turtle research is often limited by the availability of animal subjects. This availability is much less restricted on Melbourne Beach. In addition, information assimilated on such characteristics as hatchling sex ratios, migratory patterns of nesting adults and production, has broader applications with respect to whole populations. For this reason, information gathered at Melbourne Beach may better facilitate an understanding

of the life histories and ecologic geographies of these populations.

6. Public Education - Some effort should be made to enhance the realization and appreciation of Melbourne Beach as an important marine turtle rookery. Because any conservation initiative relies on public support, every effort should be made to make research results available to clarify misconceptions about marine turtles and to acquaint people with aspects of marine turtle biology and conservation.

SUMMARY

A complete census of marine turtle nesting activity was undertaken within the 21 km Melbourne Beach study area in 1985. Loggerhead nesting densities were found to average 490 nests per kilometer. Nesting of this magnitude is apparently unequalled elsewhere in the Western Atlantic. Nesting densities of Florida green turtles at Melbourne Beach averaged 13.4 nests per kilometer. Though seemingly paltry in comparison to loggerhead nesting, this represented an over five-fold increase in nesting over previous years and one of the densest recorded nesting concentrations from this endangered population. Only two leatherback nests were deposited within the study area in 1985.

The presence of beachfront lights was found to correlate negatively with areas of preferred green turtle nesting. Loggerheads were less affected by this phenomenon but did appear to abandon nesting emergences at a greater frequency in lighted areas. The spatial and temporal distributions of nesting activity were found to differ between loggerheads and green turtles. These distributions were observed to vary in accordance with the differential abilities of the two species to cope with constraints imposed by nesting site/time choice.

One hundred loggerhead, 27 green turtle, and 2 leatherback clutches were monitored throughout their incubation. Significant correlations were found between clutch sizes and the respective body sizes of nesting loggerheads and green turtles. Incubation period length was found not

to vary significantly between loggerhead and green turtle clutches, nor between three vertical zones in which the clutches were deposited.

Approximately 48 and 51 percent of the constituent eggs of loggerhead and green turtle nests at Melbourne Beach in 1985 resulted in hatchlings that successfully entered the surf. These values of reproductive success were found to be very high when compared to data from other nesting beaches. Ocean-bound success of loggerhead and green turtle nests in a model year in which no major storms strike, is expected to be approximately 63 and 58 percent. Success of loggerhead nests was found to vary significantly between three vertical zones of deposition. Success among loggerhead and green turtle nests was not found to correlate with any other nest attribute.

The most damaging cause of mortality to clutches of both species was a severe September northeaster storm. Raccoons and hatchling disorientation by beachfront lights were also significant in limiting reproductive success at Melbourne Beach. Predation of nests by raccoons was restricted to a small portion of the study area and did not correspond to areas of elevated raccoon population density. The rate of hatchling disorientation was observed to decrease dramatically following the enforcement of a regional ordinance prohibiting beachfront lighting.

High nesting densities and substantial success of deposited clutches at Melbourne Beach accounted for the production of approximately 571,000 loggerhead and 21,000 Florida green turtle hatchlings in 1985.

A P P E N D I X

Table 1. Morphological characteristics of nesting loggerhead turtles (*Caretta caretta*) encountered during sample nest marking excursions on 21 km of beach in South Brevard County, Florida, 1985. Locations are specified as one km sections, the northernmost section (1) beginning five km south of 5th Avenue, Indialantic, Florida.

				Carapace Measurements (cm)					
				Straight Line			Over Curvature		
Tag No.	Sample Nest No.	Location	Nesting Date	Greatest Length	Standard Length	Width	Length	Width	Head Width (cm)
D3863	1	3	13-14 May	91.9	89.9	64.4	97.2	87.3	21.5
D3864	2	11	13-14 May	94.2	91.2	66.4	98.5	80.0	19.5
D3865	4	18	15-16 May	92.9	91.1	65.5	99.0	91.8	22.1
D3866	5	14	15-16 May	92.1	89.5	64.3	94.0	88.1	19.5
D3867	6	12	15-16 May	99.1	97.6	73.5	106.3	92.1	18.5
D3868	7	8	17-18 May	86.2	84.7	62.5	92.3	86.2	17.8
D3869	8	7	17-18 May	93.5	91.8	68.5	99.0	91.1	19.8
D3870	9	5	17-18 May	96.1	94.2	65.1	99.5	89.6	21.7
D3878	10	3	17-18 May	103.5	101.8	79.6	111.0	101.2	21.4
D3871	11	2	19-20 May	101.0	98.4	71.4	104.6	94.6	20.0
D3872	12	5	19-20 May	100.0	97.5	74.9	104.7	94.5	21.0
D3873	13	10	19-20 May	95.1	93.8	71.1	101.2	91.7	20.0
D3874	14	10	19-20 May	103.1	101.0	74.4	108.1	97.7	24.3
D3875	15	1	22-23 May	91.7	90.2	68.5	95.1	88.8	19.2
D3879	16	2	22-23 May	86.2	85.9	65.5	91.9	82.7	17.7
D3880	17	4	22-23 May	88.3	84.9	64.2	89.5	80.5	17.9

Table 1--continued.

				Carapace Measurements (cm)					
				Straight Line			Over Curvature		Head
	Sample			Greatest	Standard				Width
Tag No.	Nest No.	Location	Nesting Date	Length	Length	Width	Length	Width	(cm)
D3881	18	17	23-24 May	96.6	94.4	70.8	101.5	89.7	20.5
D3882	19	16	23-24 May	102.0	99.5	78.6	105.4	97.0	21.8
D3883	20	14	23-24 May	95.4	93.2	69.3	98.3	90.2	21.1
D3884	21	12	23-24 May	95.7	95.0	65.2	101.6	86.8	20.5
B3576	--	11	26-27 May	--	92.7	69.5	99.8	--	--
D3885	22	11	26-27 May	98.0	94.2	76.2	99.0	94.6	19.2
D3887	23	12	26-27 May	91.1	90.2	66.5	95.7	88.8	18.8
D3888	24	13	26-27 May	91.6	89.1	70.6	94.8	94.0	19.9
D3889	25	21	26-27 May	98.5	96.5	67.9	101.8	90.4	21.0
D3890	26	18	26-27 May	90.1	88.7	67.7	94.2	86.7	18.0
D3895	--	10	29-30 May	--	93.0	70.6	100.5	94.0	--
D3896	27	9	29-30 May	100.2	98.7	75.6	105.6	97.4	21.0
D3897	28	9	29-30 May	94.4	92.8	75.5	99.3	91.6	21.0
D3898	--	10	29-30 May	--	95.0	--	99.8	--	--
D3899	29	14	29-30 May	100.3	97.8	73.0	103.0	95.6	20.7
T2318	--	13	29-30 May	--	94.0	--	103.3	--	--

Table 1--continued.

				Carapace Measurements (cm)					
				Straight Line			Over Curvature		Head
	Sample			Greatest	Standard				Width
Tag No.	Nest No.	Location	Nesting Date	Length	Length	Width	Length	Width	(cm)
D3900	30	13	31-1 June	99.4	98.1	73.0	106.3	95.7	22.4
D4001	31	14	31-1 June	103.8	100.1	73.0	107.8	99.0	21.6
D4002	32	11	31-1 June	103.2	101.4	69.0	108.3	94.2	24.0
D4003	--	10	31-1 June	95.0	94.0	71.7	100.0	91.8	19.0
SI423	--	6	31-1 June	90.7	90.1	65.6	96.7	87.2	19.0
D4004	--	5	31-1 June	97.6	94.9	71.1	100.0	97.7	21.1
D4005	33	15	2-3 June	87.7	87.3	64.4	94.9	67.0	19.0
D4006	34	16	2-3 June	97.6	95.0	76.6	102.5	92.8	22.6
D4007	35	17	2-3 June	92.0	90.8	64.0	95.9	84.3	18.8
D4008	36	18	2-3 June	94.6	92.8	66.9	97.3	90.7	23.4
D4009	37	1	2-3 June	96.8	94.9	72.0	101.8	92.8	19.9
D4010	38	11	5-6 June	101.4	99.9	73.8	108.9	97.9	20.3
D4011	39	10	5-6 June	94.1	91.8	74.0	98.0	92.9	18.0
D4012	41	16	9-10 June	95.5	93.1	70.7	101.4	90.8	17.4
D4013	42	12	9-10 June	99.1	96.8	75.6	104.8	97.7	20.1
D4014	43	16	9-10 June	102.8	100.1	79.1	108.2	99.5	20.7

Table 1--continued.

Tag No.	Sample Nest No.	Location	Nesting Date	Carapace Measurements (cm): Straight Line: Greatest Length	Straight Line: Standard Length	Straight Line: Width	Over Curvature: Length	Over Curvature: Width	Head Width (cm)
D4015	44	17	9-10 June	90.9	90.3	68.0	96.6	89.3	19.5
D4016	46	9	12-13 June	95.0	92.9	71.2	100.5	95.5	20.5
SI2239	--	1	17-18 June	--	--	--	91.8	79.2	--
D4017	47	2	17-18 June	92.9	91.1	67.1	96.8	84.9	18.9
D4018	48	3	17-18 June	82.5	80.9	58.3	87.9	84.0	16.8
D4019	49	7	17-18 June	91.9	91.0	72.0	96.3	87.2	19.9
D4020	50	5	17-18 June	91.2	89.8	69.9	96.2	92.2	18.2
D4021	51	2	17-18 June	94.2	93.7	69.1	104.0	92.4	19.0
D4022	53	3	20-21 June	91.4	90.9	67.5	97.5	88.1	17.9
D4023	--	5	20-21 June	95.5	95.2	75.2	100.7	98.8	21.7
D4025	54	3	20-21 June	92.5	91.6	70.5	97.8	90.2	20.2
D4026	--	20	23-24 June	96.0	95.6	66.0	102.3	90.1	20.2
D3112	--	19	23-24 June	--	91.7	65.5	97.5	87.0	19.5
D4028	55	18	23-24 June	92.4	91.1	69.7	99.0	91.5	19.0
D4032	56	11	24-25 June	86.6	84.8	62.0	92.0	82.1	16.9
D4031	57	11	24-25 June	95.1	92.5	74.9	99.5	93.9	20.9

Table 1--continued.

Tag No.	Sample Nest No.	Location	Nesting Date	Carapace Measurements (cm): Straight Line: Greatest Length	Straight Line: Standard Length	Straight Line: Width	Over Curvature: Length	Over Curvature: Width	Head Width (cm)
D4035	58	17	24-25 June	84.4	83.7	64.0	90.0	84.1	17.1
D4027	61	18	24-25 June	85.4	84.0	64.3	92.1	82.6	17.9
D4034	62	15	24-25 June	104.4	101.3	80.7	102.0	110.4	20.8
D4030	52	18	26-27 June	90.0	88.8	69.9	94.7	88.5	18.2
D4029	64	17	26-27 June	88.1	87.3	61.9	94.4	87.4	18.0
D3891	68	17	26-27 June	88.5	88.0	65.0	94.0	85.3	17.9
D4037	65	20	30-1 July	92.5	92.2	68.6	96.0	89.5	19.5
D4038	67	17	30-1 July	94.4	92.6	65.2	99.4	67.3	20.5
D4039	69	15	30-1 July	97.8	97.1	75.0	91.8	103.5	20.7
D4040	70	13	30-1 July	91.9	90.5	70.7	95.3	89.2	20.1
D4041	71	7	1-2 July	102.9	101.9	77.3	111.0	101.4	20.7
D4042	72	6	1-2 July	91.1	89.1	68.6	95.1	89.4	18.5
D4043	--	6	1-2 July	87.0	85.9	67.4	93.6	84.3	19.5
D4044	73	6	1-2 July	90.7	88.8	72.3	95.9	88.6	18.0
D4045	74	3	1-2 July	99.1	98.1	76.6	105.6	101.4	23.6
D4046	75	6	1-2 July	91.5	89.2	69.9	95.2	86.0	19.1

Table 1--continued.

				Carapace Measurements (cm)					
				Straight Line			Over Curvature		Head
	Sample			Greatest	Standard				Width
Tag No.	Nest No.	Location	Nesting Date	Length	Length	Width	Length	Width	(cm)
D4049	82	14	7-8 July	98.9	97.8	72.3	107.0	100.0	21.5
D4053	84	14	7-8 July	92.0	89.6	70.2	98.6	91.3	18.5
D4055	85	17	9-10 July	90.3	88.3	69.8	95.1	89.9	19.1
D4054	86	18	9-10 July	98.4	96.8	68.6	102.7	94.2	20.3
D4056	87	15	9-10 July	85.8	84.4	64.9	92.0	86.4	18.4
D4057	88	11	10-11 July	95.5	93.9	75.9	100.0	96.7	20.8
D4058	89	9	10-11 July	101.1	98.8	75.3	106.0	101.9	20.5
D4059	90	4	10-11 July	86.1	84.3	67.2	89.5	90.0	16.7
*D3869	91	6	10-11 July	93.5	91.8	68.5	99.0	91.1	19.8
C2003	--	6	10-11 July	98.7	97.4	74.0	108.5	98.5	21.0
T2088	--	13	15-16 July	95.5	94.3	68.9	103.2	91.3	20.5
D4065	93	11	15-16 July	99.3	97.7	73.8	105.5	92.5	20.9
D4063	94	9	15-16 July	98.9	96.5	72.0	104.1	91.0	19.2
D4060	95	9	15-16 July	93.3	91.5	69.2	99.0	88.5	18.0
T2201	--	2	17-18 July	92.0	90.5	67.4	95.0	88.0	21.2
D4076	96	6	17-18 July	94.5	92.1	69.5	98.0	90.9	18.6

Table 1--continued.

Tag No.	Sample Nest No.	Location	Nesting Date	Carapace Measurements (cm) Straight Line Greatest Length	Straight Line Standard Length	Straight Line Width	Over Curvature Length	Over Curvature Width	Head Width (cm)
D4077	98	3	17-18 July	97.7	95.5	68.7	103.0	92.8	19.8
D4085	102	10	22-23 July	97.5	94.0	78.1	100.3	100.1	18.7
D4075	106	10	22-23 July	93.9	92.4	70.0	97.5	89.3	18.3
D4074	107	8	22-23 July	85.9	85.4	68.1	94.0	88.1	17.0
D4091	--	14	22-23 July	90.4	89.0	67.3	95.5	88.8	17.9
D4092	--	1	24-25 July	91.8	90.0	72.5	96.9	89.2	18.8
D4093	--	2	24-25 July	90.4	88.3	73.1	--	--	19.3
H1955	--	8	26-27 July	99.9	97.8	70.7	104.7	92.9	21.9
D4072	115	8	29-30 July	98.9	94.6	75.0	101.8	91.5	21.7
D4086	116	4	29-30 July	94.2	92.2	81.3	102.1	95.0	19.5
D4073	117	10	29-30 July	90.5	89.5	69.3	97.2	91.0	18.2
D4098	119	11	29-30 July	93.1	91.9	70.9	99.6	88.5	18.8
D4062	120	19	29-30 July	91.7	89.7	65.8	98.4	88.9	18.1
*D4030	121	13	29-30 July	90.1	88.6	69.8	94.5	88.5	18.0
D4099	122	19	29-30 July	88.2	86.7	72.0	92.7	89.7	17.0

Table 1--continued.

Tag No.	Sample Nest No.	Location	Nesting Date	Carapace Measurements (cm) Straight Line Greatest Length	Standard Length	Width	Over Curvature Length	Width	Head Width (cm)
D4050	123	17	29-30 July	92.1	89.3	65.8	95.9	83.2	18.3
SI3348	--	17	30-31 July	86.3	82.2	60.8	90.5	83.9	16.1
D4112	118	13	31-1 August	88.1	87.2	62.4	95.9	83.1	17.3
*D4008	124	17	31-1 August	94.6	92.8	66.9	97.3	90.7	23.4
D4107	127	11	1-2 August	91.2	88.3	64.5	96.3	72.1	19.5
D4116	--	12	11-12 August	88.1	85.8	61.9	92.5	83.0	17.5
D4117	129	9	11-12 August	91.3	89.5	69.6	92.8	84.4	18.7
D4118	--	8	11-12 August	93.6	91.3	70.9	96.0	89.8	19.5
D4100	130	5	11-12 August	86.2	85.7	63.7	94.3	78.5	16.1
D4097	128	10	14-15 August	89.4	88.4	67.5	95.1	85.3	18.0
D4119	132	6	14-15 August	99.6	96.9	73.5	104.6	91.5	21.1
D4120	--	12	29-30 August	91.0	89.3	68.8	96.6	88.1	17.3
N				114	119	117	119	116	115
$\bar{x}$				93.9	92.2	69.8	98.9	90.3	19.6
SD				4.93	4.63	4.56	5.04	6.54	1.68
Range				82.5-104.4	80.9-101.9	58.3-81.3	87.9-108.9	67.0-110.4	16.1-24.3

*Turtle encountered and measured previously this season. Only initial measurements used in calculating means.

Table 2. Morphological characteristics of nesting green turtles (<u>Chelonia</u> <u>Mydas</u>) encountered during sample nest marking excursions on 21 km of beach in South Brevard County, Florida, 1985. Locations are specified as one km sections, the northernmost section (1) beginning five km south of 5th Avenue, Indialantic, Florida.

				Carapace Measurements (cm)					
				Straight Line			Over Curvature		Head Width (cm)
Tag No.	Sample Nest No.	Location	Nesting Date	Greatest Length	Standard Length	Width	Length	Width	
--	--	11-20	August 1985	--	102.8	74.2	109.0	97.0	13.4
--	--	11-20	August 1985	--	103.5	81.5	109.5	107.0	14.5
--	--	11-20	August 1985	--	103.5	81.2	108.8	102.0	14.2
D4024	--	15	23-24 June	102.3	101.2	83.1	107.6	104.2	15.0
D4033	63	16	24-25 June	99.7	99.4	78.0	106.5	94.2	13.1
D4036	66	16	26-27 June	108.0	107.1	82.9	112.1	103.8	14.3
SI2970	81	8	6-7 July	--	--	--	116.0	100.0	14.0
D4051 D4052	83	14	7-8 July	98.8	95.7	77.9	102.9	97.2	13.9
D3893	--	18	10-11 July	103.2	103.0	77.2	108.8	96.3	14.1
D4066	97	12	15-16 July	113.0	112.5	88.8	120.2	110.9	14.9
D4061 D4067	103	15	17-18 July	101.3	101.3	78.9	108.2	100.5	13.1
D4068 D4069	104	15	17-18 July	104.2	104.0	82.4	110.0	109.8	13.2
D4070 D4071	105	14	17-18 July	106.8	106.0	82.0	111.5	102.1	14.8
D4078 D4079	100	2	17-18 July	102.6	101.9	79.1	108.3	96.8	13.5

Table 2--continued

				Carapace Measurements (cm)					
				Straight Line			Over Curvature		
Tag No.	Sample Nest No.	Location	Nesting Date	Greatest Length	Standard Length	Width	Length	Width	Head Width (cm)
D4080 D4081	99	2	17-18 July	102.7	101.7	83.4	109.1	106.2	14.2
D4082 D4083	101	1	17-18 July	101.5	101.0	75.1	106.9	99.8	14.3
AAV046	108	20	21-22 July	99.2	99.0	74.5	102.4	92.3	18.2
SI3098	--	19	21-22 July	--	107.2	74.8	108.7	96.6	13.8
D4086 SI3096	109	15	22-23 July	100.4	99.3	73.4	105.7	92.8	14.0
D4089 D4090	111	18	22-23 July	103.4	103.5	81.2	110.2	105.2	14.1
D3894	--	16	24-25 July	100.7	98.7	79.5	106.3	105.2	13.7
*D4036	114	16	25-26 July	108.2	107.5	82.1	112.9	102.3	14.7
D4047 D4048	112	16	25-26 July	97.0	95.6	75.8	102.0	93.6	12.5
**D4084	--	13	25-26 July	86.9	83.2	67.0	97.0	94.2	13.0
D4094	--	9	26-27 July	114.0	113.5	87.3	121.2	110.1	14.3

*Turtle encountered and measured previously this season. Only initial measurements used in calculating means.

**Turtle prominently kyphotic (see text).

Table 2--continued

				Carapace Measurements (cm)					
				Straight Line			Over Curvature		Head
Tag No.	Sample Nest No.	Location	Nesting Date	Greatest Length	Standard Length	Width	Length	Width	Width (cm)
D4095 D4096	113	5	26-27 July	100.1	99.8	78.2	106.8	96.0	13.5
D4114	126	9	1-2 August	101.0	98.8	78.2	106.3	96.6	14.7
D4102	125	10	5-6 August	102.0	101.6	81.6	111.0	106.0	13.6
D4105	--	7	11-12 August	96.7	96.5	77.5	102.8	95.9	13.1
N				23	27	27	28	28	28
$\bar{x}$				102.0	101.5	79.1	108.4	100.4	14.0
SD				5.42	5.66	4.52	5.07	5.60	1.03
Range				86.9-114.0	83.2-113.5	67.0-88.8	97.0-121.2	92.3-110.9	12.5-18.2

Table 3. Characteristics of loggerhead (<u>Caretta caretta</u>) sample nests marked during the 1985 nesting season in south Brevard County, Florida. Definitions for incubation period, zone of deposition, and emerging success are given in the report text. Disturbances are symbolized as follows: C, ghost crab predation; R, raccoon predation; P, plant root infiltration; T, major tidal inundation; S, major sand accretion.

Nest No.	Deposition Date(1985)	Incubation Period (days)	Zone of Deposition	Emerging Success(%)	Disturbance
1	13-14 May	56	B	97.2	none
2	13-14 May	57	B	63.9	C
4	15-16 May	53	B	69.8	C
5	15-16 May	--	B	0	none
6	15-16 May	54	B	68.7	C
7	17-18 May	54	B	98.1	none
8	17-18 May	54	B	80.0	C
9	17-18 May	--	B	0	none
10	17-18 May	54	B	84.2	C
11	19-20 May	53	C	6.1	R
12	19-20 May	57	B	86.1	C
13	19-20 May	54	B	81.5	none
14	19-20 May	55	A	61.9	C
15	22-23 May	58	B	91.3	none
16	22-23 May	--	B	0	R
17	22-23 May	53	B	61.2	none
18	23-24 May	53.5	B	12.9	P
19	23-24 May	54	A	0.7	P
20	23-24 May	52.5	B	91.4	none
21	23-24 May	54	B	95.4	none
22	26-27 May	53.5	C	98.0	none
23	26-27 May	55	B	90.1	none
24	26-27 May	51	B	96.1	none
25	26-27 May	55	A	74.8	none
26	26-27 May	51	B	88.4	none
27	29-30 May	--	C	77.5	C

Table 3--continued

Nest No.	Deposition Date(1985)	Incubation Period (days)	Zone of Deposition	Emerging Success(%)	Disturbance
28	29-30 May	50	A	93.1	none
29	29-30 May	52	B	96.5	none
30	31-1 June	56	C	95.0	none
31	31-1 June	52	B	78.2	C
32	31-1 June	52	B	87.7	C
33	2-3 June	51	C	81.3	C
34	2-3 June	50	A	83.1	C
35	2-3 June	50	A	99.1	none
36	2-3 June	54	B	76.5	C
37	2-3 June	57	A	68.8	none
38	5-6 June	55	A	94.1	none
39	5-6 June	56	B	54.0	none
41	9-10 June	--	C	22.6	C
42	9-10 June	55	B	81.9	C
43	9-10 June	52	B	67.4	none
44	9-10 June	54	A	17.0	P
46	12-13 June	--	C	0	T
47	17-18 June	54	C	4.8	C
48	17-18 June	54	C	93.4	none
49	17-18 June	52.5	B	97.3	none
50	17-18 June		C	0	T
51	17-18 June	50	A	57.3	C
53	20-21 June	53.5	C	84.5	none
54	20-21 June	53	C	88.0	none
55	23-24 June	--	C	0	S
56	24-25 June	--	C	0	T
57	24-25 June	53	B	88.1	C
58	24-25 June	51	C	86.8	C
61	24-25 June	--	B	0	R
62	24-25 June	53	C	80.9	none

Table 3--continued

Nest No.	Deposition Date(1985)	Incubation Period (days)	Zone of Deposition	Emerging Success(%)	Disturbance
64	26-27 June	49	B	88.2	C
68	26-27 June	51	B	32.9	none
52	26-27 June	--	C	0	S
65	30-1 July	--	A	0	R
67	30-1 July	--	A	0	R
69	30-1 July	51	A	76.0	C
70	30-1 July	52	B	27.7	C
71	1-2 July	51	B	95.6	none
72	1-2 July	52	B	97.9	none
73	1-2 July	--	C	79.6	none
74	1-2 July	55	C	84.2	none
75	1-2 July	52	B	88.9	none
82	7-8 July	54	C	97.7	none
84	7-8 July	55	C	94.7	none
85	9-10 July	--	C	0	R
86	9-10 July	--	C	0	R
87	9-10 July	57	C	96.0	none
88	10-11 July	53	B	87.9	none
89	10-11 July	51	B	53.1	C
90	10-11 July	52	B	91.2	none
91	10-11 July	51.5	B	97.7	none
93	15-16 July	51.5	B	82.9	none
94	15-16 July	51	B	62.8	C
95	15-16 July	54	C	39.4	C
96	17-18 July	51	B	96.3	none
98	17-18 July	52	A	64.6	C
102	22-23 July	--	C	--	--
106	22-23 July	--	C	--	--
107	22-23 July	--	B	95.2	none
115	29-30 July	--	C	0	T

Table 3--continued

Nest No.	Deposition Date(1985)	Incubation Period (days)	Zone of Deposition	Emerging Success(%)	Disturbance
116	29-30 July	--	C	0	T
117	29-30 July	--	C	0	T
119	29-30 July	--	C	0	T
120	29-30 July	--	B	0	T
121	29-30 July	--	C	0	T
122	29-30 July	53	B	71.9	none
123	29-30 July	--	B	0	T
118	31-1 Aug.	--	B	44.3	C
124	31-1 Aug.	--	B	0	T
127	1-2 Aug.	--	A	--	--
129	11-12 Aug.	--	B	0	S
130	11-12 Aug.	--	B	0	S
128	14-15 Aug.	--	C	0	T
132	14-15 Aug.	--	A	0	S
	$\bar{x}$	52.7	--	52.7	--
Zone A	SD	2.53	--	38.0	--
	n	12	16	15	--
	$\bar{x}$	53.0	--	64.7	--
Zone B	SD	1.94	--	35.5	--
	n	40	51	51	--
	$\bar{x}$	53.8	--	42.3	--
Zone C	SD	1.60	--	43.5	--
	n	15	33	31	--
	$\bar{x}$	53.1	--	55.7	--
Total	SD	1.99	--	39.5	--
	n	67	100	97	--

Table 4. Characteristics of green turtle (*Chelonia mydas*) sample nests marked during the 1985 nesting season in south Brevard County, Florida. Definitions for incubation period and zone of deposition are given in the report text. Disturbances are symbolized as follows: C, ghost crab predation; R, raccoon predation; P, plant root infiltration; T, major tidal inundation; B, emergence blocked (see text).

Nest No.	Deposition Date (1985)	Incubation Period (days)	Zone of Deposition	Disturbance
40	5-6 June	56	B	C
59	19-20 June	51	A	none
63	24-25 June	--	C	T
66	26-27 June	53	A	B
76	1-2 July	51	A	C
77	2-3 July	54	A	none
78	2-3 July	--	A	R
79	4-5 July	51	A	none
80	5-6 July	52	A	C
81	6-7 July	--	A	P
83	7-8 July	53	B	C
92	12-13 July	54.5	A	C
97	15-16 July	56	C	none
99	17-18 July	54	A	none
100	17-18 July	55.5	A	none
101	17-18 July	54	A	P
103	17-18 July	54	A	P
104	17-18 July	56	A	none
105	17-18 July	54	B	none
108	21-22 July	52	A	none
109	22-23 July	--	A	none
111	22-23 July	65	A	none
112	25-26 July	--	A	C

Table 4--continued

Nest No.	Deposition Date (1985)	Incubation Period (days)	Zone of Deposition	Disturbance
114	25-26 July	49	A	none
113	26-27 July	56	B	T
126	1-2 August	--	A	--
125	5-6 August	--	A	--
Zone A	n	--	21	--
Zone B	n	--	4	--
Zone C	n	--	2	--
	$\bar{x}$	54.1	--	--
Total	SD	3.26	--	--
	n	20	--	--

Table 5. Clutch size and three measures of nest success for loggerhead (*Caretta caretta*) sample nests marked during the 1985 nesting season in south Brevard County, Florida. Definitions of the three measures of nest success are given in the report text.

Nest No.	Clutch Size	Hatching Success(%)	Emerging Success(%)	Approximate Ocean-Bound Success(%)
1	109	97.2	97.2	80.0
2	118	63.9	63.9	63.9
4	126	70.6	69.8	69.8
5	111	0	0	0
6	131	68.7	68.7	68.7
7	107	98.1	98.1	98.1
8	120	82.5	80.0	72.0
9	104	0	0	0
10	139	88.5	84.2	84.2
11	131	87.8	6.1	6.1
12	144	86.1	86.1	86.1
13	130	82.3	81.5	81.5
14	134	61.9	61.9	61.9
15	104	91.3	91.3	--
16	93	0	0	0
17	116	61.2	61.2	58.6
18	101	13.9	12.9	--
19	143	0.7	0.7	0.7
20	128	91.4	91.4	--
21	132	95.4	95.4	94.7
22	133	98.0	98.0	--
23	132	93.9	90.1	90.1
24	129	96.9	96.1	93.8
25	135	74.8	74.8	74.8
26	121	88.4	88.4	--
27	151	77.5	77.5	--
28	116	93.1	93.1	93.1

Table 5--continued

Nest No.	Clutch Size	Hatching Success(%)	Emerging Success(%)	Approximate Ocean-Bound Success(%)
29	143	97.2	96.5	96.5
30	119	97.5	95.0	92.4
31	165	79.4	78.2	78.2
32	163	90.8	87.7	--
33	112	81.3	81.3	--
34	124	83.1	83.1	83.1
35	109	99.1	99.1	99.1
36	136	91.9	76.5	76.5
37	141	77.3	68.8	--
38	118	94.9	94.1	86.4
39	126	54.0	54.0	54.0
41	106	22.6	22.6	--
42	127	85.8	81.9	81.1
43	132	68.9	67.4	67.4
44	112	17.9	17.0	17.0
46	135	0	0	0
47	103	4.8	4.8	4.8
48	76	94.7	93.4	88.2
49	110	97.3	97.3	--
50	102	0	0	0
51	117	59.0	57.3	--
52	121	0	0	0
53	103	87.4	84.5	--
54	108	88.0	88.0	--
55	91	0	0	0
56	91	0	0	0
57	118	89.0	88.1	--
58	106	86.8	86.8	86.8
61	126	0	0	0
62	157	80.9	80.9	--

Table 5--continued

Nest No.	Clutch Size	Hatching Success(%)	Emerging Success(%)	Approximate Ocean-Bound Success(%)
64	70	32.9	32.9	32.9
65	109	0	0	0
67	93	0	0	0
68	102	94.1	88.2	87.2
69	125	77.6	76.0	76.0
70	94	27.7	27.7	27.7
71	135	95.6	95.6	--
72	96	97.9	97.9	97.9
73	98	79.6	79.6	--
74	146	84.9	84.2	--
75	90	90.0	88.9	86.7
82	129	99.2	97.7	--
84	95	94.7	94.7	--
85	101	0	0	0
86	117	0	0	0
87	99	96.0	96.0	96.0
88	116	90.5	87.9	87.9
89	128	53.9	53.1	--
90	102	91.2	91.2	90.2
91	87	100.0	97.7	--
93	129	90.7	82.9	--
94	129	62.8	62.8	62.0
95	109	41.3	39.4	39.4
96	108	96.3	96.3	95.4
98	113	64.6	64.6	63.7
102	127	--	--	--
106	121	--	--	--
107	83	95.2	95.2	--
115	149	0	0	0
116	136	0	0	0

Table 5--continued

Nest No.	Clutch Size	Hatching Success(%)	Emerging Success(%)	Approximate Ocean-Bound Success(%)
117	96	0	0	0
118	97	46.4	44.3	--
119	110	0	0	0
120	102	0	0	0
121	119	0	0	0
122	96	72.9	71.9	--
123	86	0	0	0
124	114	0	0	0
127	107	--	--	--
128	92	0	0	0
129	114	0	0	0
130	92	0	0	0
132	124	0	0	0
UNDISTURBED NESTS				
$\bar{x}$		83.9	82.9	
SD		23.1	23.0	
n		43	43	
NESTS NOT AFFECTED BY SEPTEMBER STORM				
$\bar{x}$		65.7	63.6	55.7
SD		36.2	36.2	38.1
n		85	85	58
TOTAL NESTS				
$\bar{x}$	116	57.4	55.7	46.2
SD	18.8	39.9	39.5	40.6
n	100	97	97	70

Table 6. Clutch size and three measures of nest success for green turtle (Chelonia mydas) sample nests marked during the 1985 nesting season in south Brevard County, Florida. Definitions of the three measures of nest success are given in the report text.

Nest No.	Clutch Size	Hatching Success(%)	Emerging Success(%)	Approximate Ocean-Bound Success(%)
40	129	83.7	82.2	82.2
59	167	74.2	74.2	--
63	142	0	0	0
66	150	92.0	0	0
76	158	81.6	81.0	--
77	138	90.6	88.4	88.4
78	131	0	0	0
79	172	76.2	75.0	75.0
80	150	62.7	61.3	--
81	146	1.4	0	0
83	140	90.7	90.7	90.7
92	155	80.0	80.0	--
97	193	91.2	91.2	--
99	142	81.7	80.3	--
100	126	72.2	71.4	--
101	143	54.5	54.5	52.4
103	179	51.9	50.3	--
104	134	85.1	84.3	84.3
105	156	13.5	13.5	13.5
108	138	94.9	94.2	94.2
109	130	80.0	80.0	--
111	60*	83.3	81.7	--
112	102	0	0	0
113	155	20.0	3.2	3.2
114	152	78.9	78.3	78.3
125	179	--	--	--
126	169	--	--	--

Table 6--continued

Nest No.	Clutch Size	Hatching Success(%)	Emerging Success(%)	Approximate Ocean-Bound Success(%)
UNDISTURBED NESTS				
$\bar{x}$		78.0	76	
SD		20.7	20.9	
n		13	12	
NESTS NOT AFFECTED BY SEPTEMBER STORM				
$\bar{x}$		63.3	58.8	47.1
SD		33.5	35.0	41.5
n		24	24	14
TOTAL NESTS				
$\bar{x}$	149	61.6	56.6	44.1
SD	19.7	33.9	36.1	41.6
n	26	25	25	15

* clutch size not used in calculation of mean (see text)

Table 7. Information from recoveries of previously tagged loggerheads (*Caretta caretta*) observed on 21 km of beach in south Brevard County, Florida, 1985. Abbreviations: MB, Melbourne Beach (present study area); SI immediately south of Sebastian Inlet, Florida; KSC, Kennedy Space Center beach, Florida; CNS, Canaveral National Seashore, Florida; GA, Cumberland Island, Georgia.

Tag No.		Original	Time	Straight Line Carapace Growth (cm)	
Recent	Original	Location	Elapsed (yr)	Width	Length
D3866	G1206	MB	8	--	--
D3869	T2872	MB	3	1.7	-0.8
--	T2898	MB	3	--	--
--	SI2334	MB	2	--	--
D3880	D3180	MB	3	-0.8	1.1
--	B3576	MB	8	0.9	-1.3
D3887	D3512	MB	3	--	--
D3895	16248	MB	4	2.4	1.9
D3898	P1199	KSC	6	--	0.1
-	T2318	MB	3	--	-0.2
D4002	D3146	MB	3	2.3	0.6
D4003	SI2110	MB	2	--	--
--	SI423	SI	10	--	--
D4004	D3256	MB	3	-0.9	0.1
D4007	D3336	MB	3	2.5	2.4
--	T2716	MB	3	--	--
--	D3258	MB	3	--	--
--	SI2239	MB	2	--	--
D4023	G1306	MB	6	-1.0	2.5
D4026	C1640	MB	13	--	--
--	D3112	MB	3	-0.3	0.5
D4040	H3134	KSC	6	0.2	1.0
D4043	D3213	MB	3	0.8	0.9

Table 7--continued

Tag No.		Original	Time	Straight Line Carapace Growth (cm)	
Recent	Original	Location	Elapsed (yr)	Width	Length
D4045	SI2273	MB	2	--	--
--	C3260	MB	8	--	--
--	C2003	MB	12	-2.8	1.5
D4059	T2288	MB	3	0.2	0.6
--	T2088	MB	4	0.4	0.7
--	T2201	MB	3	0.4	0.3
D4077	T2297	MB	3	-0.5	-0.7
D4091	T2824	MB	3	0.6	0.9
--	T2372	MB	3	--	--
--	H1955	KSC	7	0.9	0.9
D4116	H1906	KSC	7	0.5	0.4
--	E9270	MB	10	--	--
D4118	FL1901	CNS	-	--	--
D3889	GA1317	GA	2	--	--
D4019	T2273	MB	3	1.2	-0.2
D4020	16483	MB	4	1.6	1.0

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